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Research Outlook 1983

RESEARCH OUTLOOK 1983

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Contents:

INTRODUCTION

INTRODUCTION

Research Outlook 1983 is the eighth in this series of reports to Congress as required by Section 5 of Public Law 94-475, 90 Stat. 2071. It describes the major research issues, trends and strategies of EPA's research program for the next half decade.

The primary purpose of EPA's research effort is to support environmental program officials and regulatory decision makers by both responding to their near-term needs for scientific and technical information and by anticipating future information needs and initiating research efforts to satisfy those needs.

This edition of the **Research Outlook** continues -- and makes more emphatic -- the issue orientation of EPA's research strategy. As with any long-range strategy document, this report is presented in broad, summary terms. The context within which this is done is a discussion of approximately 60 of the most important issues being addressed by EPA research.

Such an issue orientation is intended to achieve two things. First, it overlays a framework within which the reader can understand the relationships among EPA's many different regulatory responsibilities and associated research efforts. Without such a framework, EPA's 2,000 active research projects would present a daunting challenge to even the most determined reader. Second, the issue orientation gives our reviewers a "handle" by which to grasp and examine our overall research strategy. The issues we select, along with our research approach, are clearly presented to stimulate critical discussion.

The research process, by expanding the horizons of our knowledge, can raise as many questions as it answers. The same is true of this report. For example, have we chosen the correct set of issues to address? Is our understanding of the status and context of these issues adequate? Do we correctly identify the crucial information gaps or bottlenecks to progress? Is our strategy with regard to providing the scientific information needed to fill these gaps cost-effective?

Prior to publication, the chapters in this report were reviewed by more than 100 scientists, research managers and environmental regulatory officials within EPA, other federal agencies, academia, private industry and public interest groups. They asked the above questions and more, and their critiques not only influenced the content of this report but also, in the long run, the content of EPA's research program itself. In this sense, the **Research Outlook** is the first step in the research planning process. This report provides the outline. The details are filled in by the annual planning cycle followed by the detailed description and implementation of the research projects.

Because of its summary nature, this report may leave the reader desirous of greater detail or project-level information. Other research summary documents, which focus on a shorter time horizon and contain a far greater level of detail, will soon be made available.

Report Organization

This edition of the **Research Outlook** is divided into eight chapters and two appendices. The first appendix contains three resource scenarios and associated research activities. The second lists the technical reviewers who critiqued earlier drafts of this report.

Each of the eight chapters generally consists of the following:

Introduction: Defines the area of research covered in the chapter.

Legislative Mandate: Lists the laws which mandate EPA involvement in general, and research in particular, with regard to subject of the chapter.

Background: Gives some history and context for the overall discussion. Introduces EPA's objectives and the major areas of focus for the issues that follow.

Major Research Issues: Each chapter contains discussions of from five to twelve issues. The issues are selected using one simple criterion -- what are the key scientific and technical information gaps which are impeding efforts to assure adequate protection of health and the environment? The issues are the heart of this report. For each issue the following information is presented: a description of the issue indicating why the missing information is necessary; what is known, and unknown, about the issue; EPA's research role in the context of other major associated research programs; EPA's research strategy and specific research approach; and major anticipated research products or milestones.

Cross-cutting Issues

It bears repeating that this is a strategy document. It is not intended to be, nor would it serve its purpose if it were, an exhaustive litany of all of EPA's research projects. There are many areas of active EPA research which are not discussed in any depth in this report. They are excluded for one of two reasons. First, they may contribute exclusively to issues which are of lesser importance or priority than the ones selected for this report. An example of one such issue is EPA's non-ionizing radiation research effort. Once a significant component of EPA's research program, studies of non-ionizing radiation conducted during the past five years have produced a good deal of useful information. Based upon this situation, EPA's regulatory office determined that sufficient data already existed upon which to base its regulatory decisions. As a result, non-ionizing radiation research is being de-emphasized within the overall research program and is not considered to be a major issue warranting inclusion in **Research Outlook 1983.**

The other reason that a research area may not appear in a particular chapter is because it cuts across several of the chapters. Examples of such cross-cutting issues are quality assurance, risk assessment methods, regulatory and technical support, and information transfer. In some cases, such an issue of consequence to several chapters is discussed in depth in the chapter for which it holds the greatest significance. This allows a more detailed discussion of the cross-cutting issue, although the discussion is somewhat distorted by the limits of a particular chapter. In other cases, aspects of a cross-cutting issue are discussed in several chapters.

Research Priorities

It is impossible to predict in detail what environmental research will be necessary over the next half decade. The context for this research is much too dynamic. Legislative mandates may be altered, policies may shift and public concerns evolve. All these forces will shape the details of our future research program. In addition, that program will shape itself as new research information either highlights the need for added investigation or resolves the problem being investigated.

In a large sense, every one of the issues discussed in the following document has a very high priority. The issues are closely intertwined -- the products from one issue providing the substrate for another. Taken together, the approximately 60 issues discussed in the following chapters make up one unified research program. Given this context, there are some major research needs which can be identified, with some certainty, as paramount:

Ground-water pollution. To control the pollution of ground water, it is necessary to be able to monitor underground pollutant plumes and to predict their behavior. We are testing equipment and developing models to do both, and are investigating a number of techniques to destroy or isolate toxic substances.

Water quality determination. The use ascribed to a body of water determines the quality at which that water must be maintained. A water-quality based regulatory approach requires the development of accurate, and inexpensive, methods for determining water quality.

Toxicity measurement for complex mixtures. Determining the toxicity of a complex mixture of wastewaters as a whole would be a far less expensive process than identifying each of the components of the wastewater and then attempting to determine their combined effect. We are developing bioassay and other techniques that should improve our ability to determine the human health implications of such complex mixtures.

Toxicity prediction for chemicals. Toxic chemical testing is an expensive and time-consuming process. Research is being performed to develop more accurate and less expensive test methods and to improve existing screening methods.

Determination of environmental exposure. In order to more precisely determine the effectiveness of various air pollution control strategies, we need to know exactly how much pollution people inhale. We will be testing personal monitors which measure CO in order to develop accurate exposure data which can then be used as a surrogate for determining exposure to other air pollutants.

Acidic deposition source-receptor relationship. We must have better information on the relationships between the sources of acidic deposition precursors and their eventual effects on the receptors of that deposition. This is an issue with enormous resource implications for the industrial and commercial sectors.

Predictive modeling. In order to provide the necessary tools to state and local decision makers responsible for controlling air pollution, we will be refining air pollution models to better predict the behavior of air pollutants under certain meteorologic and topographic conditions.

Biological pesticides. There has been rapid growth in the development of biological pesticides. EPA is performing research for use in evaluating the possible human health and environmental (non-target) risks of such agents.

Chapter One
HAZARDOUS WASTES

HAZARDOUS WASTES

Outline:

Introduction
Legislative Mandate
Background
Major Research Issues:

- **Issue:** What designs make surface impoundments more secure?
- **Issue:** How can air pollution from volatile organics be controlled?
- **Issue:** What information is needed to optimize incineration?
- **Issue:** How can sampling and analysis methods be improved?
- **Issue:** How can health risks be assessed more accurately?
- **Issue:** How can non-volatile compounds be measured?
- **Issue:** How can the quality of sample data be assured?

INTRODUCTION

The safe treatment and disposal of hazardous wastes is one of America's major public issues. Hazardous wastes from industrial production have been common for decades, but only recently has major legislation focused on the magnitude of the problem and on research to help find remedies to it. Because today's waste problems differ from those in the past in terms of volume, toxicity and resistance to treatment, remedies will need to exploit new technologies and procedures.

Hazardous wastes now include many man-made compounds that do not exist naturally. Some of these compounds are slow to biodegrade. In 1981, in excess of 50 million metric tons of hazardous wastes including organic chemicals, pesticides, acids, caustics, flammables and explosives were generated in the United States. The extent of health problems caused by hazardous wastes is still largely undefined. Concentrations at which chemical wastes cause adverse effects, their latent period before manifestation, the routes of hazardous waste exposures and the chronic effects of such exposures on people and the environment are difficult to determine.

Congress has legislated, and EPA has developed, a hazardous waste program. The major goal of this program is to reduce risks to public health and the environment by ensuring sound management of hazardous wastes.

The EPA research program for hazardous waste in fiscal year 1983 is allocated $33 million. These resources are distributed among the research disciplines as follows: engineering and technology, 55%; monitoring systems and quality assurance, 22%; environmental processes and effects, 15%; scientific assessment, 5%; and health effects, 3%.

LEGISLATIVE MANDATE

EPA's mandate for hazardous waste research comes from the Resource Conservation and Recovery Act (RCRA) of 1976, as amended; the Federal Water Pollution Control Act (FWPCA), as amended; and the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980. RCRA is the vehicle for defining, at the national level, the minimal guidelines and requirements necessary to protect human health and the environment from hazards posed by the treatment, storage or disposal of hazardous wastes.

RCRA also gives the EPA authority to establish national standards to ensure proper management, transportation, treatment, storage, and disposal of hazardous wastes. RCRA requires EPA to develop lists and criteria for determining what constitutes a hazardous waste, standards that have to be met by handlers of hazardous wastes, technical standards for issuing permits to hazardous waste facilities and requirements for the authorization of state hazardous waste programs.

The Federal Water Pollution Control Act, which sets federal policy regarding the discharge of oil or hazardous substances into U.S. navigable waters, directs EPA to develop, promulgate and revise regulations pertaining to such discharges. FWPCA authorizes EPA to initiate civil action for violations and to undertake actions to mitigate damage to public health or welfare caused by discharges. Although regulations implementing FWPCA already exist, they require periodic updating based on new information and improvements in control technology.

The Comprehensive Environmental Response, Compensation and Liability Act provides authority for a federal response to the release or threatened release of hazardous substances. CERCLA also includes the Post-Closure Liability Trust Fund. As a means to achieve its goals, CERCLA established the Hazardous Substance Response Trust Fund, also known as Superfund. While a significant amount of scientific activity is under way relating to Superfund activities, this activity is of a technical support nature and therefore is not appropriate for inclusion in this **Research Outlook.** Many of the results from the research described below, however, will be of use at some point in the Superfund effort.

BACKGROUND

Hazardous waste problems have certain features that, taken together, determine the most effective response. Wastes at industry sources or already in disposal sites need to be identified, characterized and classified as to their composition, quantities and potential health effects. Sites to be used for disposal and technology to be employed at the sites need to be evaluated to assure that future discarded wastes are adequately monitored and controlled. Permits for operating sites and for disposing of wastes need to provide permittees with the appropriate requirements to be followed. Instrumentation to monitor sites and to assure compliance or to detect and measure problems needs to be effective for various types of wastes.

All of these activities and requirements demand a solid scientific base of technically sound, field-tested and proven procedures that supply accurate and timely information for solving a specific hazardous waste problem. Moreover, the data, information and decision-making processes must be of known quality to assure consistent quality control, since much of the regulatory authority for dealing with hazardous wastes will be transferred to state agencies. States will need monitoring methods for obtaining verifiable data. Furthermore, revisions of the hazardous waste regulations will occur periodically and must have a scientific data base that is technically sound.

A major problem facing EPA is the relatively recent recognition of the dangers from waste and the dearth of scientific data on the subject. For example, scientific analytical methods have been developed for many volatile and semi-volatile compounds, but less progress has been made in developing methods for non-volatile compounds. EPA's research program is designed to fill major information gaps, both to provide near-term solutions and to establish a scientific base for the longer-term.

MAJOR RESEARCH ISSUES

The key hazardous waste research issues are:

- What designs will make landfills and surface impoundments more secure?
- How can air pollution from volatile organics be controlled?
- What information is needed to optimize the use of land treatment for hazardous waste disposal?
- What information is needed to optimize the incineration of hazardous wastes?
- How can the accuracy and reliability of methods for sampling wastes and waste sites and for biologically and chemically analyzing the sample data be improved?
- How can the extent of health effects and risks from hazardous wastes be defined sufficiently to allow adequate levels of protection to be determined while avoiding costly over-control? Can rapid and economical tests be developed which can be accurately extrapolated to humans?
- How can non-volatile compounds be measured?
- How can EPA assure that the analyses of samples taken from hazardous wastes yield data of known quality?

Issue: What designs will make landfills and surface impoundments more secure?

Landfills and surface impoundments have been used for years as inexpensive means of disposing of hazardous wastes. The design of many of these sites followed haphazard, conflicting and sometimes erroneous information. Some of the problems of today, particularly ground-water contamination, are testimony to the inadequacy of the earlier approach. With that legacy in mind, one of EPA's proposed research programs is attempting to develop the information to make landfills and surface impoundments more secure. The research focus is on the life span and efficacy of flexible, synthetic membranes and/or impervious soils used as liners for the hazardous-waste sites.

Flexible membrane liners (FML's) and impervious soils can be placed on the bottom of a waste site before the hazardous waste disposal begins; they can also be used to cap sites once they are filled. The liners, if installed and maintained correctly, contain wastes and isolate them from the influx of surface or ground water that might cause the waste to escape from the site. When used as a supplement to clay or soil barriers, FML's can dramatically increase their effectiveness. The key design criterion for using FML's and impervious soils is whether they are compatible with the wastes they are to control: some wastes may pass through certain materials used in liners, other wastes may chemically degrade liners. EPA research projects evaluate the compatibility of synthetic liners and soil liners with wastes and investigate techniques to monitor the integrity of liners.

EPA has the leading role in federally sponsored FML research, although there are a few other organizations conducting their own programs. A small program conducted by the U.S. Army Corps of Engineers is looking at liner compatibility with military wastes (e.g., explosives). Private companies are developing new liners, but their product designs are hampered by the lack of precise descriptions of the specific waste mixtures which would require liners.

EPA's research approach is to develop tests to determine the compatibility of liners with various classes of organic and inorganic compounds at concentrations likely to be seen in waste mixtures. The tests will be for effects on porosity, permeability, and the response of the liners to chemical and mechanical stress.

A method will be devised to predict likely leachate compositions based on various concentrations of waste compounds and chemical reactions among them. The liners will then be installed in test beds and evaluated under actual field operating conditions. Monitoring and measuring equipment will be developed to determine the durability of the liner and its ability to contain and control specific waste mixtures. The output of the research will be a set of recommendations for using liners at waste sites.

Research regarding surface impoundment liners will also focus on repairs to leaking liners. New methods and instrumentation are needed to detect leaks. The current method is to take periodic samples from monitoring wells around an impoundment. Research is focusing on the use of geophysical methods and sensor technology to monitor the unsaturated soil zone. This monitoring will detect pollutants from a leaking liner before they reach the ground water. Once a leak has been detected, however, methods are needed to plug it. Techniques will be investigated for bonding a patch to the leaking liner.

A manual with landfill and surface impoundment design recommendations will be available in 1983. It will be updated periodically as more is learned about waste characteristics and liner compatibility. The leak-sealing methods will be developed in 1984. In future years, emphasis will be put on leak detection.

Other means to control the flow of waste-site leachate will be studied to match the type of control methods with the nature of the leachate problem and the characteristics of the waste site. This work is important because ground water and surface water will become contaminated as they come into contact with the leachate plume. This, in turn, can affect drinking water aquifers and could, depending on the seriousness of the contamination, lead to the closure of drinking water sources.

The rate of leachate flow is determined by the physical and chemical characteristics of the waste and, to a lesser extent, by the subsurface geology. The key factor here is the amount of water that percolates through the waste. This is affected by the amount of water in the wastes, entering the landfill, or in the surrounding land. Rain-water inflows to landfills, for example, can cause leachate flows that might be avoided if the waste were isolated from the inflow.

The research at EPA is developing control methods and technology for abating the flow of leachates as well as methods for collecting and treating leachates prior to their discharge. Such technology includes bentonite dams, slurry trenches and French drains. Technical handbooks presenting spill prevention and treatment/removal techniques will be published in 1984. Biological controls will include the use of the existing or modified microbes that will decompose waste to inert or harmless substances. The result of this research will be a set of alternatives for resolving problems at waste sites with migrating leachate. Monitoring techniques for the unsaturated soil zone will be described for use in determining the likelihood of future escape of leachate to the ground water. The results will be available for field use by 1985.

Issue: How can air pollution from volatile organics be controlled?

Waste materials disposed of in a landfill or surface impoundment may produce air pollution when either the materials themselves volatize (evaporate) or when products of chemical reactions among the materials evaporate. Such volatile organic compounds (VOCs) found in the air around landfills and surface impoundments may produce health and environmental effects and unpleasant odors.

EPA's research program is developing techniques for measuring and predicting the amounts and rates of VOC emissions. One prediction method will be used to estimate the amounts that will move up through a soil cover. Research projects will identify the effects of barometric pressure and waste decomposition on the movement of volatile substances. Results will be available in 1984.

Another prediction method will describe the movement of VOCs laterally through the soil. After field verification is completed in 1983, the method will be used to determine effective VOC control technologies (e.g., vents and barriers) and to decide how far buildings must be from a site to avoid exposing people.

The verified prediction and measurement methods will be used to evaluate the magnitude of the VOC problem so that site designers and permit reviewers can compare performance estimates with actual emissions. This evaluation and comparison will provide the technical basis for potential regulatory action and for identifying future research needs.

Issue: What information is needed to make optimum use of land treatment for hazardous waste disposal?

Land treatment of hazardous wastes involves tilling (incorporating) it into the soil to enable the natural biological, chemical and physical processes of the soil to decompose, destroy and detoxify the hazardous compounds. The major benefits of using this natural assimilative capacity of soil are two-fold: first, it can be a very cost-effective approach, and second, through land treatment such processes as biological degradation, chemical transformation and simple immobilization can convert some wastes into innocuous compounds rather than being stored in a hazardous form in landfills and surface impoundments.

The concept of land treatment for hazardous wastes is not new. Petroleum companies have used the technique for more than 20 years with good success in treating substances such as tank bottom residues. EPA's research will build upon the information garnered from these earlier successes and will extend the land treatment option for a broader range of hazardous wastes for which conventional disposal is economically and environmentally undesirable. Research will focus on understanding the subsurface physical, chemical and biological processes that affect the movement and degradation of wastes.

Land treatment studies begin in the laboratory, then move to a greenhouse environment and, finally, to actual test sites if good treatability potential is indicated. EPA currently has a test area of more than 100 acres which is available for land treatment studies. Laboratory tests will be made of actual waste mixtures supplied by cooperating industries. The mixtures will be characterized to determine the amounts and types of waste compounds they contain. The land at the test site will be characterized to determine its physical and chemical parameters and likely biological responses to the wastes. The mixture will then be spread on the soil and tilled.

Measuring and monitoring instruments and sample taking will reveal the degree of biological activity taking place. Soil column testing in the laboratory will determine the migration of pollutants and the loading rates. Variables will be evaluated to determine the optimum land treatment process. Such variables include loading rate of waste initially applied to the land, different application and incorporation methods, amount of soil moisture, pH, and soil fertility.

To monitor land treatment sites for contaminants, several statistical detection procedures will be employed. The monitoring network design will be based on the statistics of spatially correlated variables. By using these techniques, a range of correlation coefficients can be computed to minimize cost and maximize coverage of the sampling design. Since the monitoring must be repeated over time, the monitoring network design will include time-series analysis to minimize cost while maintaining an acceptable probability of coverage.

The hypothesis testing of monitoring data will compute both the type I error (alpha, probability of a false positive) and type II error (beta, probability of a false negative). Such procedures will be appropriate for multiple variate analysis with unequal variances. EPA will develop guidance on the design of monitoring networks for use by regional personnel in issuing permits.

Issue: What information is needed to optimize the incineration of hazardous wastes?

Incineration is an effective method for destroying hazardous wastes. Its use in the past was limited by its relatively high cost when compared to landfill and surface impoundment alternatives. Now, though, these alternatives are becoming more expensive and less available for certain wastes and geographical regions. Extensive knowledge has been produced under this program and is being applied under the Superfund program. Further information may help to optimize incineration conditions in order to achieve the maximum destruction of wastes at the lowest cost. EPA research will develop scientific data for existing incinerators to describe the best operating conditions for incinerating certain types of hazardous wastes and to define air emissions which may result from the incineration of certain types of hazardous wastes using various incineration processes.

The program will run test burns in pilot-scale incinerators as well as in commercial incinerators. EPA has a Combustion Research Facility in Pine Bluff, Arkansas, in which to conduct the pilot-scale test burns. The facility is fully instrumented to allow determination of the various parameters associated with incineration in rotary kiln and liquid injection incinerators.

The research program will first characterize waste for thermal destructability and then burn these wastes at the EPA research facility to assess the effectiveness of the incineration process. The parameters to be evaluated include temperatures in the incinerator, dwell time of the wastes in the high temperature zone, the Btu content of the waste, the oxygen content of the mixture, the optimal air/waste ratio, waste injection methods, the need for an afterburner to assure complete destruction and the types of analysis and sampling techniques needed. One major concern to be investigated involves the establishment of thermal destruction conditions that are necessary to eliminate the formation of additional toxic substances which may form under current incinerator conditions. Additionally, air emissions from the incineration will be characterized to determine if, and at what concentrations, hazardous compounds or toxic metals are being emitted.

The information collected from the tests will be used to allow scale-up to full-sized incinerators. Field verifications will determine likely operating efficiencies and optimal methods to be used in actual hazardous waste control sites. The composition and quantities of combustion products produced will be analyzed to ensure that no harmful pollutants are released to the environment. EPA has established a permit assistance team to help permit writers to evaluate permit applications. The results of this research will help that team to assess the data included in permit applications and to establish necessary trial burn parameters and criteria for particular wastes to be burned in specific types of incinerators.

In addition to the studies of conventional incineration processes, a research program will investigate advanced high-temperature industrial processes. The program will field test full-scale operating units to evaluate unit performance and to determine conditions that would limit the processes' effectiveness.

Issue: How can the accuracy and reliability of methods for sampling wastes and waste sites and for biologically and chemically analyzing the sample data be improved?

Some of the current state-of-the-art methods for analyzing hazardous wastes and waste site samples have not undergone the rigorous evaluation necessary to define standard confidence limits for the data they produce. Such limits, stated as the "plus-or-minus" confidence limit of each data point, are especially important when the measured concentration is near the regulatory decision limit used to determine whether a waste is hazardous or a site sample indicates a health or environmental problem.

Current programs use analytical methods based on technology developed for EPA's water monitoring programs. Confidence limits of these methods can now be applied to the analysis of aqueous samples. However, only limited information is available for their application to hazardous waste samples and samples from waste sites (e.g., soils, sediments and solids).

Because of this limitation, EPA has placed a high priority on developing quality assurance information on various methods. A data base will be developed consisting of standard reference materials containing priority pollutants. This will serve as a single, traceable source of known purity standards for RCRA monitoring activities.

EPA researchers are also evaluating new technology and developing improved quality control and assurance procedures to reduce the cost of analyses while simultaneously narrowing the confidence limits of the resulting data. Guidance documents will be produced that define the confidence limits of the current methodology and describe improved protocols and technology. Finally, standardized methods will help to support specific RCRA regulatory requirements such as methods for characterizing waste as hazardous due to toxicity, corrosiveness, ignitability, etc.

One EPA study will improve the current extraction procedure for the RCRA toxicity characteristic. The procedure now in use can only be applied to a small list of toxic materials and does not yield an extract that is amenable to bioassay. The improved procedure, based on a flow-through column of the waste, should yield an extract suitable for bioassay. The procedure is being evaluated to determine its reproducibility and how well it reflects actual waste disposal situations. Results are expected in 1984. Other research includes developing standard protocols for other RCRA characteristics such as ignitability (flash point), corrosiveness and reactivity due to toxic gas generation. These protocols will undergo testing to establish their precision and accuracy during 1984 and 1985.

Another research effort is evaluating the use of bioassays for determining the toxicity of hazardous wastes. Standard protocols for the Daphnia Magna and Ames Test bioassays will undergo single lab and collaborative testing during 1983. Other bioassays will be identified and undergo similar protocol development and evaluation during 1984-1985.

The evaluation of methods to analyze hazardous wastes will continue. Collaborative testing of an analytical protocol for measuring medium concentrations (from one part per million to 100 parts per thousand toxics concentration) will be completed in 1983, and evaluation of methods to extract organic and inorganic samples (soxhlet vs. liquid-liquid extraction for organics; digestion procedures for inorganics) will be reported on in 1984. A specific analytical method for dioxin in hazardous waste is being standardized. Methods are required that detect dioxin at very low concentrations (100 parts per trillion) even in the presence of higher concentrations of other substances. An initial dioxin protocol will be provided during 1983. Efforts will then be initiated to provide similar protocols for dibenzofuran, another highly toxic compound, by 1985.

Projects to improve the quality of hazardous waste data and reduce the cost of analysis are under way. One analysis method, known as pulsed positive ion negative ion chemical ionization mass spectroscopy, has the potential for improving the sensitivity of mass spectroscopic analysis of very toxic materials. The method is being evaluated and a protocol will be produced in 1983. Tandem mass spectroscopy for the quick screening of hazardous wastes will be reported on in 1984. Fourier transform infrared spectroscopy is also being investigated for use in the analysis of high concentrations of hazardous waste.

Issue: How can the extent of health effects and risks from hazardous wastes be defined sufficient to allow adequate levels of protection to be determined while avoiding costly over-control? Can rapid and economical tests be developed which can be accurately extrapolated to humans?

Section 3001 of RCRA requires EPA to promulgate criteria for identifying the characteristics of hazardous wastes and to provide a listing of hazardous wastes. Because of the large number of wastes to be screened, it may prove useful for the EPA to develop a battery of rapid, inexpensive bioassay prescreening tests that prioritize hazards from complex chemical mixtures by determining which wastes are most important for toxicological characterization. If the prescreening shows a waste to be potentially hazardous, then a second method may be used to determine affected health endpoints and the environmental levels of exposure at which effects can be observed. Results from this second method will be used in the process of analyzing a waste for listing or delisting as a hazardous waste. Currently existing methods have not been validated for complex mixtures and not all endpoints have rapid, inexpensive test methods to quantify potential effects. Research will be conducted to develop such methods.

Which testing procedures can be used to estimate relative degree of hazard is the major issue for determining health hazards from chemicals. The goal is to develop a group of tests that will allow estimates of relative hazard to be made at reasonable costs. EPA's approach to solving this problem is to validate shorter-term toxicological testing procedures for ranking hazards to human health. Currently that ranking is obtained by more conventional, but more expensive test procedures.

To predict the ranking of hazards to human health, it is necessary to identify two different types of toxicity: responses which result from genotoxic effects, on the one hand, and toxicity to target organs, on the other. This research is essential for biological testing of results obtained in the field to be validated for human health effects. In some cases substantial evidence indicates qualitative correlations between short-term and more conventional testing procedures. However, use of data from the short-term tests for quantitative estimates of health risk is not yet practical. EPA research projects will establish the cause-and-effect relationship between the short-term indicator of adverse health effects and overt diseases and will determine the quantitative relationship between does-responses, the indicators and the diseases. The first three years of the research will emphasize establishing empirical relationships between indicators and the production of diseases. Key goals of this work are the determination of which testing methods are clearly irrelevant to human health effects and the establishment of cause-and-effect relationships between indicator and disease for the final validation of health effects models.

By 1985, research will complete an evaluation of an inexpensive, qualitative prescreening protocol integrating existing methods for predicting biological activity (chronic toxicity, mutagenicity, neurotoxicity, etc.) The report will assess the efficiency of the protocol for application to RCRA materials such as complex mixtures of raw wastes and leachates. The protocol is being developed to provide the data to support setting of first-level priorities using an integrated battery of tests. Also by 1985, initial field testing will be completed for an integrated protocol of a second-level, confirmatory battery of existing tests. The protocol will quantify levels of dose-response using a single set of test animals for the specific toxic hazards of carcinogenicity, mutagenicity system toxicity, neurobehavior and teratogenicity. When proven, this protocol, by quantifying risks, could be used as a basis for determining if a waste is hazardous.

Issue: How can non-volatile compounds be measured?

Current EPA monitoring methods are, to a large degree, applicable only to the volatile and semi-volatile compounds that can easily be analyzed by gas chromatography and GC/MS. Many potentially toxic compounds (e.g., larger molecular weight compounds) are not easily analyzed by the current protocols. While monitoring methods exist for some of the less volatile compounds -- for example, liquid chromatography can be used for some pesticides -- current routine monitoring procedures cannot adequately analyze intractable compounds (those not easily removed from water or similar matrices) or non-volatile compounds. This is significant because there is a considerable proportion of non-volatiles in samples from some hazardous waste sites. EPA research will attempt to identify or develop analytical methods to measure these of compounds.

Two methods being studied are high pressure liquid chromatography and triple stage quadrapole mass spectroscopy. The mass spectroscopy method will be initially evaluated in 1983 for its application to non-volatile toxic chemicals. Pending the success of that evaluation, the method will be fully developed in 1985.

Issue: How can EPA assure that the analysis of samples taken from hazardous wastes yield data of known quality?

Analyses of hazardous wastes are being conducted under the auspices of EPA throughout the United States. Rigorously defined analytical protocols are required to assure that the laboratories conducting the analyses collect accurate, quality-assured data. Quality assurance is needed to:

- develop/evaluate analytical standards for instrument calibration,
- develop/evaluate reference solutions for evaluations of laboratory performance,
- develop/evaluate reference materials (soils, sludges, etc.) of known composition for intercomparison studies,
- validate sampling, analytical and biological methods, and

- determine equivalency of new sampling, analytical and biological methods.

EPA has developed and is applying analytical protocols that support both RCRA and CERCLA monitoring responsibilities. Quality assurance is a key part of this work. EPA will also maintain a repository of calibration standards through 1985. This repository will support RCRA requirements, as will reference materials and solutions developed by EPA to evaluate laboratory performance and to ensure comparability of analytical data. On-site evaluation of RCRA laboratories and additional support will also be performed by EPA.

Chapter Two
WATER QUALITY

WATER QUALITY

Outline:

Introduction
Legislative Mandate
Background
Major Research Issues:

- **Issue:** What are appropriate methods for determining attainable uses for a water body?
- **Issue:** How should laboratory-derived water quality criteria be modified to apply to site-specific conditions?
- **Issue:** How can wasteload allocation techniques be used to translate applicable water quality standards into allowable pollution discharge loads?
- **Issue:** What is the best way to assess the impacts of the ocean disposal of wastes?
- **Issue:** What are the dynamics and biological availability of pollutants in sediments?
- **Issue:** What analytical test procedures and quality control methods are necessary for accurate measurement of habitat? What monitoring is needed to quantify water pollutants?
- **Issue:** What are the key technical and scientific factors that limit the effective treatment and use of sludges from municipal and industrial wastewater treatment?
- **Issue:** Are occurrences of infectious diseases increased by certain wastewater treatment or sludge disposal practices?

INTRODUCTION

EPA's water quality research program includes both an emphasis on a field-oriented water-quality based approach to pollution control, and consideration of the chemical and biological impacts of the ocean disposal of wastes. The research will include studies of ecological effects, process and systems engineering, health effects and monitoring methodologies.

With the nearing completion of effluent guidelines and the application of technology-based controls, EPA will now give more emphasis to the implementation of a water-quality based approach. States will focus on those water bodies for which pollution abatement and control decisions are most needed to prevent or reverse the impairment of a designated use.

The water-quality based approach to water pollution control matches control requirements to site-specific uses. Each use of a body of water (e.g., recreation, fishing) calls for a minimum water quality. Once the use of a stream segment or water body is defined, various alternatives to achieve or maintain the water quality appropriate to the designated use can be evaluated, and cost-effective controls can be selected. This process involves consideration of existing water problems, of community goals for the use of water resources, and of costs and benefits of various control strategies.

Although significant progress has been made in developing water-quality based controls, additional technical information is needed to facilitate pollution control decisions. The technical information must provide decision makers with a basis for the selection of water pollution controls. Standardized analytical and monitoring methods are needed for the assessment of local water quality through bioassay and biological survey, as well as for compliance with water quality standards and discharge limits specified in permits.

Although water pollution control programs will increasingly emphasize the water-quality based approach, the technology-based approach that has been applied over the past decade will be continued. The Agency's construction grant program will continue to be a major part of the Agency's water pollution control efforts.

Over the last year, substantial progress has been made on promulgation of final, technology-based standards, based on the best available technology. EPA has completed most of the technical and economic studies needed to support the promulgation of Agency effluent guideline regulations for major industries. For those pollution sources not subject to effluent guidelines, permitting agencies will issue individual best professional judgment permits for pollution discharges.

The second major water quality research issue is ocean disposal of waste. As a result of the decision in City of New York v. EPA, 543 F. Supp. 1084 (S.D.N.Y., 1981), EPA is proposing revisions to existing ocean dumping regulations. Under these revisions, EPA will consider and balance all the relevant statutory factors of Section 102(a) of the Marine Protection, Research and Sanctuaries Act in making permit decisions. This approach requires careful assessment of the role of the oceans and coastal waters in the assimilation of municipal and industrial waste and dredged materials. It also requires the ability to predict the impacts of ocean disposal, to evaluate alternative disposal options, to select appropriate disposal sites for specific wastes, and to detect disposal-related problems.

The ocean disposal research program will provide the information necessary to support scientifically defensible decisions with regard to ocean disposal waste management. EPA, in conjunction with other federal agencies, will also seek to establish uniform criteria and methods for determining unreasonable degradation or irreparable harm to the disposal sites. Ocean disposal issues are expected to be a major EPA concern over the next five years.

The water quality research program for fiscal year 1983 is allocated a total of $30.6 million. This total is divided among three subgroups: water quality research, $14.6 million; municipal wastewater research, $11.1 million; and industrial wastewater research, $4.9 million. The total resources for the water quality program are distributed among the major research areas as follows: engineering and technology, 34%; environmental processes and effects, 26%; monitoring systems and quality assurance, 18%; health effects, 12%; Great Lakes research, 8%; and scientific assessment, 2%.

LEGISLATIVE MANDATE

The Clean Water Act and the Marine Protection, Research and Sanctuaries Act both address protection of the nation's water quality. The objective of the Clean Water Act is to restore and maintain the chemical, physical and biological integrity of U.S. waters. The objective of the Marine Protection, Research and Sanctuaries Act is to regulate the types and amounts of materials which, if dumped or discharged into ocean waters, could adversely affect human health, welfare, amenities and the marine environment, ecological systems and economic potential. The latter act requires compliance with the London Dumping Convention, to which the United States is a contracting party.

BACKGROUND

Although much progress has been made in establishing a scientifically sound data base for making water quality management decisions, major information needs remain. EPA research will focus on the following problem areas. First, it is possible that the national water quality criteria are inappropriate for certain water bodies, thereby imposing unnecessary control costs. Imprecise linkages between in-stream criteria and water uses may make it difficult to define the benefits of achieving the criteria for particular water bodies.

Second, there is a need to give greater consideration to sediment impacts. Current water quality criteria address effects in the water column, yet many toxic pollutants and nutrients end up in sediments. It is difficult to assess with confidence the importance of sediment contamination, or to relate pollutant levels in sediments to effluent discharges.

Third, reliable and low-cost methods of identifying certain chemical pollutants are being developed.

Fourth, more information is needed on chemical class interactions with the nutrients and pollutants ingested by aquatic life forms. Availability of this type of information would greatly improve the states' ability to understand the biological health of their waters.

Fifth, more research is needed on fundamental control processes in order to make more accurate assessments of costs and benefits. In addition, information is needed on the performance, costs and water quality impacts of innovative and alternative (I/A) technologies (constructed under the I/A provisions of the Clean Water Act) and of advanced treatment technologies.

Sixth, the quantities of sludge and septage from treating wastewater are large. More information is needed regarding beneficial uses of these materials as a disposal option. Municipalities and industry need accurate information about the process engineering of a broad range of sludge treatment and disposal options.

Seventh, there are insufficient data to fully evaluate the occurrence of infectious and chemically induced diseases which may result from current and anticipated wastewater-sludge treatment and disposal practices. Additional information is necessary to assure that treatment processes preclude human health hazards.

Eight, developing site-specific water quality criteria using the chemical-by-chemical approach can be costly. There is a need for new toxicologic testing methods, applied directly to effluents and receiving streams, which can predict chemically induced toxic effects in humans and aquatic organisms. There is also a need to develop new protocols for developing site-specific criteria which are less resource intensive.

MAJOR RESEARCH ISSUES

EPA's research programs will provide scientific products which address the concerns raised above and assist the states in the implementation of the water-quality based approach. The major issues being addressed by EPA research are:

- What are appropriate methods for determining attainable uses for a water body?
- How should laboratory-derived water quality criteria be modified to apply to site-specific conditions?
- How can wasteload allocation techniques be used to translate applicable water quality standards into allowable pollution discharge loads?
- What is the best way to assess the impacts of the ocean disposal of wastes?
- What are the dynamics and biological availability of pollutants in sediments?
- What analytical test procedures and quality control methods are necessary for accurate measurement of habitat? What monitoring is needed to quantify water pollutants?
- What are the key technical and scientific factors that limit the effective treatment and use of sludges from wastewater treatment?
- Are occurrences of infectious diseases increased by certain wastewater treatment or sludge disposal practices?

Issue: What are appropriate methods for determining attainable use for a water body?

The water-quality based approach focuses on protecting water uses. EPA has proposed that states may employ a "use-attainability analysis" to help determine realistic water use goals for specific water bodies. To do so, the existing system is assessed to determine the overall health of the aquatic environment, the maximum biological potential is assessed, and the physical habitat features necessary to achieve desired uses are determined. Following the development of these data, costs and benefits are compared and a decision is made with regard to the proper control levels needed to attain a specified use.

There is currently considerable information that could be used to assess the health of aquatic environments, but there is no systematic method for integrating it into a comprehensive, useful and accurate statement of the condition of a water body. EPA will continue to assess and improve existing methods, and will combine the most suitable physical, chemical and biological measures into an overall assessment protocol.

In coordination with the states, EPA will develop protocols to aid in field assessments of specific sites. These protocols will be flexible, and will be arranged in such a way that state and local officials can compare the benefits of different levels of pollution control.

Part of the use-attainability analysis is a determination of the biological condition of a body of water. To conduct such analyses, states need better assessment procedures. EPA is evaluating current biomonitoring methodology, and is designing new methods. The factors to be considered in determining the biological condition of an aquatic system are water quality, physical habitat, hydrology and biological interactions. EPA will develop a method to combine data from these categories into a description of the condition of the aquatic system, extent and probable causes of degradation, potential for recovery and possible corrective measures. For example, one project is examining the use of fish community analyses as a substitute for a complete biotic analysis. The goal of this research is to produce a set of guidelines for use in assessing the overall conditions of an aquatic ecosystem. The guidelines will be produced by 1984. They will be reviewed, evaluated and field tested so that, by 1986, a valid set of guidelines should be available.

To predict the levels of use that could be attained in a body of water -- the second step of the use attainability analysis -- requires research to detail overall water-body conditions. At some point a water body approaches its maximum biological potential and cannot realistically be improved further. The problem facing the states will be how to determine the biological potential of specific water bodies when only limited analytical techniques and resources are available. EPA's research program will develop methods to describe the potential of aquatic ecosystems and will demonstrate the methods on waterways in various regions of the country.

The traditional approach to determining biological potential has been upstream-downstream studies. These studies are costly because each stream must be studied twice. They are also imprecise because it is uncommon to find a clean upstream site sufficiently similar to the downstream area. Better methods are needed.

Current research is aimed at estimating biological potential by correlating regional patterns of land use, geology, soil types, potential natural vegetation, climate and topography with physical, chemical and biological characteristics of streams. Several projects are under way. In Ohio, 100 field sites will be used to determine whether regional patterns correlate with stream characteristics and aquatic community traits. In Oregon, biological information is being combined with fish collection records and historical surveys as a way to estimate system potential. In Montana, fish data bases will be correlated with regional terrestrial characteristics. Results from these studies will include maps that show "attainability regions" for the studied states and an indication of whether computerized fish data may suffice for future use attainability analyses. This effort will be completed in 1985. If biological and chemical correlations are encouraging, future work will extend the methods to other regions.

The third part of the use attainability analysis is to determine the physical habitat features needed for a desired use. One possible approach is to correlate specific levels of use with specific environmental requirements for those uses. EPA research will develop site-specific methods to determine water quality criteria, and the means to relate these criteria to uses. Physical habitat guidance will be developed for other environmental characteristics such as hydrology and physical habitat features (e.g., benthic substrate, sediment quality, riparian characteristics, channel morphology and in-stream cover). This information can be used to help decide whether it is more cost-effective to attain a use by improving the water quality or by changing the physical habitat conditions.

EPA's research program will identify and quantify the physical habitat conditions required for attaining selected beneficial uses for water bodies. Initial effort will focus on factors that are needed for maintaining a healthy biological community rather than on improving fishing or the assimilative capacity of the water body. Data for the research will be collected from other federal agencies and states. If the data are found to be inadequate, a research program will be designed to obtain the data necessary. One approach being considered is a computerized data base of organisms and their environmental requirements. The data base would be structured so that either the expected species at a site or the required environmental conditions for specific species could be determined.

Planned research results include:

- Identification and recommendation of biomonitoring methods applicable to use attainability analysis, 1984.
- Evaluation of methods for using fish community measures as a surrogate for more intensive surveys of the entire ecosystem, 1985.
- Development of procedures for determining biological potential of stream ecosystems based on ongoing studies. (Oregon, 1984; Ohio, 1985).
- Definition of selected physical habitat criteria for stream ecosystems, 1986.
- Development of an aquatic organism toxicity data base and protocol for developing site-specific criteria for biotic communities which are habitat limited, 1984.

Issue: How should laboratory-derived water quality criteria be modified to apply to site-specific conditions?

As EPA and the states emphasize a water-quality approach to pollution control, water quality goals will be defined for water bodies by designating the use to be made of the water and by setting the criteria necessary to protect the use. These criteria are numerical or narrative descriptions of the concentration of pollutants which cannot be exceeded if the uses of the water body are to be met.

In many cases, states adopt national water quality criteria developed by EPA laboratories for achieving general levels of quality. However, because these criteria are laboratory-derived, are meant to apply nationwide, and are used to protect all types of aquatic systems, they cannot take into account site-specific factors. The national criteria may be under- or over-protective at a specific site for three reasons: first, species at a site may be more or less sensitive than those used to derive the laboratory-based criteria; second, the physical and chemical characteristics of the water at a site can alter the biological availability and toxicity of polluting substances; and third, aquatic organisms can adapt to pollutant levels via a variety of physiological processes. EPA's research program is developing the information needed to describe the modifications necessary to make the national criteria more site-specific.

The problem regarding species sensitivity differences arises because the national criteria are based on the responses of trout, salmon, and penaeid shrimp to pollutant loadings. These organisms have been shown to be especially sensitive to some materials and, therefore, their responses may not be the proper basis for establishing water quality standards at a site populated with differing species. The species sensitivity differences will be resolved by developing a data base that describes aquatic organisms' acute and chronic responses to different levels of toxic compounds. The data base will help states or permit writers relate species to acceptable pollutant loads for maintaining water uses. Species data also can be used to develop criteria for water bodies in which habitat conditions limit biological diversity. Existing data will be used to identify species/compound combinations that need further testing before they can be put into the data base. Early indications are that site-specific criteria which consider species sensitivity may change existing criteria at some sites by as much as two to three orders of magnitude. Results of the research will be available in 1984.

The second problem with the national criteria -- that physical or chemical characteristics of water systems alter toxic effects -- has been demonstrated in a number of cases. For example, hardness, pH, suspended solids and salinity are known to influence the concentrations and bio-availability, and thus the toxicity, of some heavy metals, ammonia and other chemicals. Research into the effects of water's chemical and physical properties on toxicants will be conducted with chemical models. One model will develop empirical relationships between a compound's toxicity and the major water variables.

A third problem is the fact that aquatic organisms can adapt to pollutant levels via a variety of physiological processes. Research has shown that aquatic organisms produce detoxifying substances when under stress. These substances act as a sink, binding contaminants that, if unchecked, could result in mortality. It is important that this adaptive process be fully understood and properly accounted for and measured in environmental assessments, especially those pertaining to use attainability, standard setting and wasteload allocations.

Planned research results include:

- Feasibility report on using chemical speciation models to derive site-specific criteria, 1983.
- Report on feasibility of using organism toxification-detoxification concepts for the development of site-specific criteria, 1984.
- Field validation of protocols for derivation of site-specific water quality criteria, 1984.
- Development of protocols for modifying national water quality criteria for marine waters, 1984.

Issue: How can wasteload allocation techniques be used to translate applicable water quality standards into allowable pollution discharge loads?

For a pollution discharge permit to be issued, Total Maximum Daily Loads (TMDLs) must be developed to determine what pollutant levels will support the designated uses. A wasteload allocation (WLA) procedure then allocates the allowable pollution load among dischargers. The WLA process, which considers both point- and non-point sources of pollution, must ensure that adequate margins of safety are incorporated into the control methods. At present, the WLA process generally works by applying the results of mathematical models to allocating wasteloads.

A series of WLA models is being developed and evaluated. They will range in complexity and scale of application from simple, steady-state, basin-scale screening models to dynamic models that predict transport and fate, as well as environmental exposure, for both conventional pollutants and potentially toxic chemicals. Many models are available for WLA analyses but most have not been field-validated.

Model users need information on the precision, reliability and applicability of each technique, in order to match appropriate models to site-specific problems. They also need descriptions of the key chemical, physical and biological variables that influence the pollutants; characterizations of the ecosystem at risk and the wastes to be discharged to it; and a better understanding of the relationship between specific discharge limit parameters and actual impacts on site-specific water uses. In addition, each model will require a clearly written users' guide to facilitate effective use by the states.

EPA's research program will focus in the short term (one to two years) on: manual and data-base generation, development of WLA technical guidance, expanded user assistance through the Center for Water Quality Modeling, improvement in organic pollutant transformation and transport kinetics (particularly bio-oxidation and benthic sediment-water column interactions) the linkages to effects measures/models for factoring in risk, and testing of these models in mesocosms and field situations to assess utility and reliability. For the intermediate term (two to three years), the program will focus on metals process research and use of geochemical models for WLA, and on improved ability to handle nutrients and carbon (conventional pollutants). The need for a longer term (four or more years) effort is being evaluated. Such a program would be designed to produce more meaningful WLA techniques for different metal species, to assemble the appropriate technology to assess benefits and costs of WLA strategies in complex, multiple discharge situations, and to relate complex effluent parameters to impacts on water uses.

In addition, EPA research will develop and test biomonitoring and bioassay field techniques for WLA screening, ecosystem response characterization, and bioaccumulation and persistence evaluation of chemicals. Similarly, research will continue to develop and test the sensitivity, cost effectiveness and utility of chemical measurement techniques to characterize wasteloads and receiving waters for WLA purposes. Results will include upgraded and evaluated models and supporting analytical techniques to predict concentrations of toxic organics, metals and conventional pollutants (e.g., oxygen-demanding substances, nutrients) likely to occur in waters subjected to different total maximum daily loads and candidate wasteload allocations. Furthermore, techniques will be developed to link these concentrations with probable impacts and, therefore, to various "use designations."

Planned research results relating to wasteload allocation include:

- Development and compilation of environmental process rate coefficients and related data bases for application in wasteload allocation, 1984.
- Development and field testing of a generic toxicity protocol for toxicity wasteload allocation, based on effluent bioassays, 1985.
- Production of a set of models that address toxic organics, metals and other pollutants to determine total maximum daily loads and wasteload allocations ranging from current steady-state model to model(s) facilitating time variant exposure and loading variability, 1983-1986.

Issue: What is the best way to assess the impacts of the ocean disposal of wastes?

The disposal of wastes into oceans, estuaries and coastal waters is either severely restricted or tightly regulated. Future public policy may result in decisions which will be based on predictions about the ecological consequences of proposed ocean outfalls and ocean dumpings. EPA has embarked upon a research program to better predict the hazards of disposal of wastes at ocean sites. The Agency will conduct this research in coordination with the U.S. Army Corps of Engineers, USGS, NOAA and the U.S. Fish and Wildlife Service.

Ocean outfall research focuses on the relationship between effluent characteristics and the quality of receiving waters. Major areas of investigation include models to describe ecosystem assimilative capacity, interactions between contaminants in waste mixtures, field validation of effluent toxicity tests, and the effectiveness of different effluent treatment processes in reducing environmental impacts.

Models of assimilative capacity can reveal factors which can limit degradation and irreparable harm to an ecosystem. One existing model predicts the changes in number of species, biomass and abundance of benthic invertebrates along different pollution gradients. The model is based on the concept that benthic succession is a function of the organic enrichment of sediment. It can be used to predict environmental changes at such sites as sewage outfalls and pulp mill waste discharge pipes. There is another available model which uses an index to quantify the benthic succession changes. EPA's research will extend existing models or develop new ones to determine the impact of waste materials on fish and other marine life. Researchers will also seek to discriminate among the effects of different materials in discharges, including organic and chemical contaminants and nutrients.

Interactions between waste substances will be the subject of similar research. Such interactions may determine the gross toxicity of the discharges. Researchers will identify the contaminants with interactions that pose the greatest ecological threat. The results of these studies are expected to indicate treatment options that will be most effective in the control of toxic waste disposal impacts.

Field validations of the effects of ocean waste discharges have rarely been attempted in the past. One validation method involves the application of bioassays to sediment samples collected at increasing distances from an outfall pipe. The bioassay results can be compared to the structure of the benthic community. Research will be continued to verify effluent toxicity estimates with field studies.

The effectiveness of different effluent treatment processes will be investigated as well. Sewage treatment to modify the levels and forms of nutrients, BOD, pH, suspended solids, priority pollutants, and coliform content has seldom been evaluated in relation to the impact of the treatment process on the marine environment. Studies will determine the toxicological properties of municipal wastes that have received a variety of primary, secondary and non-conventional wastewater treatment. Toxicity to benthic organisms will be determined by adding particulates from the different treatment processes to unpolluted reference sediments. To determine toxicity to the pelagic biota, effluents at environmentally relevant concentrations will be added to ecosystem simulators.

Ocean dumping research will develop and verify procedures to better assess impacts associated with disposal of municipal sewage sludge, dredged material and certain industrial wastes in the ocean. Research will focus on dumpsite characterization, waste characterization, exposure and effects assessments to determine the likelihood of hazard, and dumpsite monitoring.

Dumpsite characterization research will describe the physical, chemical and biological features of a site to the degree necessary for input into models that may predict the transport of wastes and the subsequent exposure of marine life.

Waste characterization studies will investigate categories of waste eligible for possible ocean disposal. The hazard potential of each type of waste varies according to dispersion characteristics, chemical and toxic properties, persistence and the presence of residue-forming contaminants.

The exposure assessment research will develop models that accurately replicate ocean disposal conditions. EPA will develop a hierarchy of models organized by temporal and spatial resolutions required for disposal decisions, and by needed type of information (e.g., water, sediment or biota).

To assess the effects of ocean disposal, short-term screening methods and long-term predictive methods will be developed. Verification of the biological results is expected to be the most complex part of this research, and will therefore receive the most attention.

Procedures to monitor dumpsites for long-term effects will be developed to aid in determining whether a dumpsite location should be discontinued or the dumping of certain wastes should be limited. Monitoring data will also be used to verify the predictions resulting from hazard assessment protocols.

Planned research products include:

- Methods Manual for conducting sediment toxicity surveys near ocean outfalls, 1983.
- Reports on persistence and fate of pollutants in marine food webs, 1985, and report on discharge conditions at ocean outfalls necessary to protect marine ecosystems, 1986.
- Hazard assessment protocols to permit a better evaluation of the impacts of ocean dumping, 1986.
- Procedures to monitor dumpsites for chronic long-term effects, 1985, and
- Dumpsite selection protocols to identify appropriate dumpsites for a selected waste to minimize the impact of ocean dumping, 1986.

Issue: What are the dynamics and biological availability of pollutants in sediments?

Sediments are the ultimate sink for most pollutants in marine, estuarine and lake ecosystems. Consequently, pollution concentrations in sediments are generally many times greater than those in the water column. For most pollutants, the amount found in sediment contaminants represents a sizable portion of the total pollutant load. For hydrophobic compounds, sediments contain the majority of the load. Thus, to understand fully the fate and effects of toxic compounds in aquatic ecosystems, comprehensive data are needed about the dynamics and bio-availability pollutants in the sediment reservoir.

The emphasis of current EPA research is on sediments of oceans and estuaries. The research will seek to: develop models of the transport and fate of pollutants, determine the bioavailability of sediment-associated pollutants to benthic organisms, determine the availability of sediment-associated pollutants to pelagic organisms, and measure rates and factors regulating pollutant degradation.

Research on the physical transport and fate of particles will be used to validate predictions of area-wide impacts of dredge spoil disposal and sewage discharges. Research will also improve the understanding of the effects of variable current speeds, vertical density profiles, settlement rates and physical-chemical interactions. Based on results of sensitivity analyses, it should be possible to provide more effective monitoring to determine impacts. Laboratory experiments will identify the factors controlling particle aggregation and disaggregation and their influence on settlement rates. Other experiments will assess the impact of filter-feeders on the settlement of various types of particulates.

As the aqueous-to-solid phase partitioning is a function of the type of particle (e.g., clays, humics, etc.), it is necessary to determine the frequency distribution of particle types in natural waters and to determine the sorption isotherms for the dominant particle types. Combining laboratory and field data with suitable sediment transport models will generate predictions of the distribution of nearly all pollutants.

The research to determine the factors regulating bioavailability of sediment-associated contaminants to benthic organisms is being approached in two ways. First, through the continued development and testing of selective extraction techniques. And, second, through the determination of equilibrium sorption isotherms for the various geochemical phases of sediments (e.g., clays, humics, bacteria, etc.) and for the bioavailability of the contaminants associated with each phase. With this information, it should be possible to predict in the laboratory the bioavailability to ecosystems of contaminant-spiked sediments and, eventually, of natural sediments of known phase composition.

Perhaps the dominant research question to be answered concerning the sediment reservoir is whether the contaminants, such as metals and non-volatile organics, are "trapped" or whether they re-enter the pelagic food webs, potentially leading to human consumption. One possible transfer mechanism to pelagic food webs is the direct or indirect consumption of contaminated benthos by fishes. Studies of the importance of trophic transfer have generated conflicting results; in some cases ingestion of contaminated prey is the dominant uptake route, whereas in other studies trophic transfer makes a trivial contribution to bioaccumulation.

A promising research approach to the study of trophic transfer to fish is to relate the uptake of pollutants from food and water to the bioenergetic requirements of the fish. The advantage of developing and verifying this model is that it may be used with adsorption data to predict the importance of different uptake routes for different species and contaminants. The utility and critical assumptions of this model will be tested on a variety of benthic species and fishes in the laboratory. Field verification will compare predicted versus actual body burdens at several trophic levels by using several of the pollutant tracers.

Other tests of the bioaccumulation model will look at reciprocal transfers of benthic organisms from clean and contaminated sites to predict uptake and depuration rates. The mussel Mytilus sp. will be used as the test filter-feeder.

Finally, studies will be undertaken to determine the importance of degradation, resuspension and sediment-water fluxes in controlling the distribution of contaminants. The effects of biological activity on these pollutant fluxes and, conversely, the effects of pollution on the rate of biological activity need to be studied. These studies will be done with controlled experiments in microcosms and flumes as well as in the field. Results will be useful as input parameters to the fate and bioaccumulation models and as a guide to the management of contaminated sediment.

The same questions about sediment contaminant effects in marine water also apply to freshwater environments. Many toxic materials are bound to suspended solids and eventually concentrate in the sediments of lakes and streams. EPA scientists seek to determine whether these sediment contaminants adversely affect aquatic ecosystems or whether the sediments become a long-term repository for toxic substances.

Research on the biological effects of freshwater sediment contaminants is needed to determine whether acute or chronic toxicity is caused by toxic material associated with sediment, to determine whether the sediments are a source of contaminants for bioaccumulation to levels of concern for human consumption, and to develop laboratory methods for assessing or predicting effects of sediment contaminants. Current EPA research addresses two of these areas. The role of sediment contaminants in acute toxicity is being examined through a combination of field and laboratory studies, and methods are being developed to assess the acute effects of sediment contaminants.

Planned research results include:

o Determination of the biological effects of contaminated sediments at field sites and an assessment of the need for sediment criteria, 1983.
o Improved process descriptions for mass transfer and biokinetics of toxic chemicals between the bottom sediments and water column in aquatic systems, 1985.

Issue: What analytical test procedures and quality control methods are necessary for accurate measurement of habitat? What monitoring is needed to quantify water pollutants?

Habitat is a dynamic, site-specific combination of physical, chemical and biological components. The design of a site-specific management program for a particular water use will depend on a determination of the state of these components and the means to monitor their interactions. In the absence of a means to monitor water body dynamics and interactions in the water and sediment, it is difficult to adequately define the integrity of a waterway.

One of the key monitoring problems is the need to identify waterborne organic compounds and classes of compounds. At present, the ability to identify and quantify concentrations of organic compounds is limited, and monitoring methods with quality assurance support are even more limited. Subcellular biochemical mechanisms offer a potential monitoring tool that can explain the interactions of mixtures of pollutants at particular sites. These biological mechanisms may also become screens for measuring attainment or maintenance of a particular use by a water body. One such mechanism is toxicity -- a bioassay which has been standardized to a degree. Other bioassay procedures need to be standardized so that comparable data can be gathered among site-specific investigations.

EPA will provide standardized analytical monitoring methods as well as quality assurance for the adequate performance of biological, chemical, physical assays and the monitoring of ambient water quality. EPA's efforts include cooperative activities with the American Society of Testing Materials (ASTM) and the U.S. Bureau of Standards. The research should include the use of subcellular biochemical systems, more sensitive chemical analysis, and the development of protocols for site-specific assays of habitat.

Monitoring of the organic and inorganic pollutants at a water site is limited because at present only about 250 chemical and physical parameters have been identified for monitoring under the technology-based regulation of wastewater discharges. Thousands of compounds, most of which have not been identified, have been detected by gas chromatographic and mass-spectrometer (GC-MS) analytical techniques. These compounds represent only about one-half of all the organic compounds present in tested waters, as estimated from measures of total organic carbon. Less is known about the nature of the other half of the organic compounds loading wastewaters and receiving waters. Efforts are needed to improve our knowledge of the interactions of these organic compounds with inorganic chemical moieties, especially within the context of the wasteload allocation and criteria modification processes.

EPA will develop analytical methods and quality assurance for the measurement of the chemical pollutants and environmental adducts of those pollutants. Included in the research will be the organic and inorganic materials which have been detected in discharges but which are not presently monitored.

Planned monitoring results include:

- Monitoring methods for measuring priority pollutants in sludges, 1984.
- Risk assessment methodology for assessing multi-media risk for a variety of disposal options, 1984-1985.
- Combination of industrial survey and field monitoring of effluents to characterize variability in ten major industrial discharges, in order to develop relationships between effluents and water use impacts, 1985.
- Chemical methods to measure toxic forms of metals, 1985.
- Design, based on existing data and hydrological

science, of sampling protocols that provide for better characterization of chemical water quality given variation in natural flow and effluent variability, 1986.

- Laboratory test methods and data interpretation methodology to permit estimate of risk to the biological organism from intermittent, fluctuating exposure, 1986.
- Reliable, inexpensive methods for analyzing toxic pollutants, 1986.

Issue: What are the key technical and scientific factors that limit the effective treatment and use of sludges from wastewater treatment?

The costs for sludge treatment and disposal represent a major portion of the overall cost of wastewater treatment. Moreover, the potential for environmental impacts from the disposal of sludge is significant. Consequently, research is needed to define optimal sludge use or disposal options.

The methods to assess sludge disposal options will be refined, with research developing both methods to determine ecosystem resiliency or stresses resulting from disposal of sludges and methods to predict the human health effects from sludge exposures. The latter could include bioassays or other toxicity tests for both health and ecosystems. Other research is needed to develop ways to mitigate risks through sludge treatment or disposal. Such research will include analysis of the cost vs. performance of engineering designs for various treatment and disposal options.

Other sludge-related research is need to provide an improved understanding of the sources of heavy metals, toxic organic compounds and other objectionable constituents in municipal wastewaters, to develop epidemiological data on the use of processes to inactivate organisms and viruses in sludges, and to improve risk assessment methods for decisions on alternative means of sludge management.

In developing needed fundamental data about new processes for improved sludge stabilization, reduction, energy recovery and use the research program will assess integrated disposal options. The major planned products of this research include:

- Design guidelines on sludge treatment technologies, with cost and performance data, that focus on innovative anaerobic sludge digestion processes, energy recovery, pathogen reduction, and more efficient thermal conversion processes, 1986.

- Feasibility report on the use of genetically engineered methagenic bacteria for improving the reliability and increasing the rate of anaerobic digestion, 1985.

Issue: Are occurrences of infectious diseases increased by certain sludge disposal practices?

The land application of sludge will be studied to determine the effects of this disposal option on the incidence of human infectious disease. EPA is encouraged by the potential of this disposal method because it recycles nutrients, conditions the soils, and may help to limit waterway contamination. Health studies will determine whether land disposal can proceed without increasing health risks.

Epidemiological studies have been initiated to evaluate health hazards. Results from these studies will provide data that can be used to determine the effect of various pretreatments and application techniques upon disease occurrence.

Studies on the survival and transport of pathogens will be continued. Virulent enteric viruses that occur in domestic wastes have considerable environmental survival potential. These viruses can be transferred directly to people or transported from waste-amended soils to surface or ground waters used for recreation or drinking water. Roundworms (Ascaris) have also been identified as a pathogen of concern in sludge because the ova stage of this parasite is believed to bé extremely resistant to environmental degradation. However, definitive data on its survival is lacking.

Carefully controlled field studies are continuing to define the survival and transport limits of the disease-causing organisms. These field data, coupled with epidemiological data on exposed populations, will provide assistance in making sound judgments on the limits of recycling of domestic wastes.

Major planned products of this research include:

- Water quality health criteria for fresh water in recreational use, 1983.
- Bioassay testing methods to assess the effectiveness of alternative wastewater control technologies, 1985.
- An assessment of EPA's epidemiological data, 1986.

Chapter Three
DRINKING WATER

DRINKING WATER

Outline:

Introduction
Background
Legislative Mandate
Major Research Issues

- **Issue:** What data and methods are necessary to improve the extrapolation of toxicological data on potential carcinogens in drinking water?
- **Issue:** Do organic by-products from chlorination pose health risks? What methods can control these by-products? Are alternative disinfectants safer?
- **Issue:** What water treatment technologies are applicable to small communities?
- **Issue:** What new methods are needed to analyze organic contaminants?
- **Issue:** How should quality assurance requirements be incorporated into the compliance program?
- **Issue:** Are geophysical monitoring techniques applicable to drinking water problems?
- **Issue:** Does subsurface biotransformation of pollutants help to protect underground sources of drinking water?

INTRODUCTION

State and local governments have the main responsibility for drinking water quality. A growing population is increasing demands on the water supply while, at the same time, chemical contamination of water sources appears to be increasing. Water management decisions are becoming both more complicated and more difficult.

State governments need help in addressing major problems related to drinking water quality. In a list of state/EPA agreements, support for drinking water responsibilities emerged as the major EPA research function requested by state governments. State government decision makers are especially concerned about revisions of the National Interim Primary Drinking Water Regulations (NIPDWR) due in 1984-1985, when new regulations for a variety of synthetic and volatile organic chemicals will also be considered.

Additional scientific data are also needed as input into new regulations. For example, disinfectants and disinfectant by-products, as well as safe alternative disinfectants, must be evaluated.

BACKGROUND

The primary goal of this EPA research program is to develop the scientific and technical data needed to assure safe public drinking water systems. Much of the drinking water research program is designed to provide information to state and local water authorities and to develop the information needed for changes to drinking water regulations. The three major components of the program are: research to support implementation of the EPA drinking water regulatory program, protection of ground-water resources, and development of the scientific basis for state implementation and compliance programs.

In health research, the primary purpose is the development of information on the toxicology and human health risks associated with substances commonly found in drinking water. Other major aspects of the health research program are the development of chemical analytical methods for determining the identity and concentration of contaminants, and the assessment of technologies for controlling such substances.

The drinking water research program for fiscal year 1983 is allocated \$23.3 million. These resources are distributed among the research disciplines as follows: health effects, 39%; engineering and technology, 32%; environmental processes and effects, 20%; monitoring systems and quality assurance, 8%; and scientific assessment, 1%.

LEGISLATIVE MANDATE

The Safe Drinking Water Act (SDWA), P.L. 93-523, as amended, requires EPA to establish drinking water regulations to protect human health and welfare. The NIPDWR regulations fulfill that requirement by specifying maximum chemical and biological contaminant levels (MCL) allowable in drinking water.

Another EPA drinking water role, described in a memorandum of understanding with the Food and Drug Administration, defines EPA's responsibilities with respect to drinking water additives.

The Safe Drinking Water Act also grants EPA the responsibility and authority to conduct drinking water research. Section 1442 of the SDWA specifically authorizes EPA to engage in research concerning: the occurrence and health effects of chemical and biological contaminants in drinking water, the analytical procedures for monitoring contaminants, the applicability of treatment technologies, the protection of underground drinking water sources and the exploration of scientific questions for emerging problems.

MAJOR RESEARCH ISSUES

As EPA satisfies the specific requirements of the SDWA and implements safe drinking water programs, the drinking water research and development program becomes focused on specific programmatic considerations, monitoring, and new problems that become apparent. This orientation of the program produces data about: low-cost, innovative technologies to supply drinking water; control of toxic organic and inorganic chemicals; the methods to detect, measure and monitor precise contaminant concentrations in water; techniques to describe toxicity of contaminants; and specific information about organic contaminants, disinfection by-products, additives, corrosion problems and compliance problems. The research will also expand our fundamental knowledge of basic environmental processes and drinking water health impacts.

The major drinking water research issues in this **Research Outlook** reflect both this problem-solving orientation and the need for monitoring data to support proposed NIPDWR changes. The issues addressed in this chapter are:

- o What data and methods are necessary to improve the extrapolation of toxicological data on potential carcinogens in drinking water?
- o Do organic by-products from chlorination disinfectants pose health risks? What methods can control these by-products? Are alternative disinfectants safer?
- o What water treatment technologies are applicable to small communities?
- o What new methods are needed to analyze organic contaminants?
- o How should quality assurance requirements be incorporated into the compliance program?
- o Are geophysical monitoring techniques applicable to drinking water problems?
- o Does subsurface biotransformation of pollutants help to protect underground sources of drinking water?

Issue: What data and methods are necessary to improve the extrapolation of toxicological data on potential carcinogens in drinking water?

The issue stated above is generic in that it applies to all activities involving assessing the carcinogenicity of chemicals in the environment. At the same time, it specifically applies to drinking water because a number of chemicals identified as common contaminants of drinking water have been shown to be carcinogenic in some animals.

Many efforts to quantify the health risks of these chemicals have been based on the "no threshold" assumption that very low doses of the chemicals can alter genetic material and have a carcinogenic effect. Nevertheless, if a chemical produces cancer without direct interaction with the genetic material, that is, through a non-genotoxic mechanism, there would be some question as to whether this no-threshold assumption is appropriate. EPA is currently evaluating both of the possible mechanisms -- genotoxic and non-genotoxic -- which may produce cancer, in order to develop appropriate extrapolation models for the chemicals found in drinking water. The key research question is, what experimental data are necessary to differentiate between chemicals which may act as tumor initiators (which are usually genotoxic carcinogens) and tumor promoters (non-genotoxic carcinogens)?

EPA shares interest and information in this research issue with other federal regulatory agencies -- primarily the Food and Drug Administration (FDA), the Occupational Safety and Health Administration (OSHA) and the Consumer Product Safety Commission (CPSC). FDA has a substantial research program involving oral exposures. OSHA's interest is primarily in the inhalation route. Other federal research agencies are studying the mechanisms of chemical carcinogenesis but the objectives of the various basic research programs generally do not emphasize the critical problem of risk assessment, which is of major concern to EPA and the other regulatory agencies.

The work that EPA will carry out has two objectives: to establish the criteria for determining whether a chemical is acting by a tumor-initiating versus a tumor-promoting mechanism in a particular target organ, and to establish which chemicals shown to be carcinogenic and of frequent occurrence in drinking water should be treated as tumor promoters for purposes of quantitatively estimating their risk.

EPA has helped to develop an initiation/promotion assay model in the rat liver and is extending the work to mice. Use of these animal models plus the application of biochemical methods to assess interactions of chemicals with DNA will help to improve evaluations of the relationship between a chemical's genotoxic activity and its ability to produce cancer, and will enable researchers to develop measures of tumor-promoting activity. Chemicals known to promote or initiate tumors will be used to validate the ability of different parameters to differentiate accurately between genotoxic and non-genotoxic carcinogens. The results of this research will help to determine the most appropriate model for different chemicals in risk assessments and, further, will improve our understanding of the implications of extrapolating from high to low dose.

This research approach may be useful because, with the rat and mouse models, cell changes occur at frequencies much higher than do tumors. This means that EPA could develop interspecies extrapolation models for both cancer-producing mechanisms using relatively small experimental groups at a considerable savings compared to conventional lifetime experiments.

Currently, the major scientific information gaps are the lack of adequate criteria to identify clearly chemicals that act through tumor-promoting mechanisms, the lack of information concerning tumor-promoting activity of chemicals identified as common contaminants of drinking water, and the lack of an adequate methodology to assess the health risk from exposure to these chemicals.

EPA's research in 1983 and 1984 will further refine the models based on the findings of the liver tumor studies in rats and mice. In 1984 and 1985, experimental data will be developed to classify liver carcinogens in drinking water that are likely to cause health effects. By 1985, EPA research will produce a theoretical basis for differentiating between a non-threshold and a threshold mechanism of tumor induction. A model will be developed to estimate health risk from the threshold mechanism. Research in 1985 and beyond will validate extrapolation models used to arrive at acceptable levels of chemicals in drinking water. This work will focus on development of systems to validate interspecies extrapolation through the use of primary in vitro cultures of human tissues as well as appropriate animal tissues.

Issue: Do organic by-products from chlorination pose health risks? What methods can control these by-products? Are alternative disinfectants safer?

It is known that drinking water disinfectants react with the organic material in source waters to produce a variety of by-products. The formation of trihalomethanes in drinking water is a well documented example of such a reaction. Chlorinated water has been found to possess mutagenic activity measurable in the Ames Salmonella assay. It is also known that a great many other products of chlorination besides the trihalomethanes have the ability to alter genetic structure. EPA research has made major contributions in this area.

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 cancer-causing agents but it is also essential to use water treatment techniques which keep waterborne infections at their current low levels. However, there is still no indication that any alternative treatment to chlorination is significantly safer. The relative hazards associated with the use of each of the disinfectants and their by-products have yet to be determined. To build the data base needed to arrive at the safest possible means of disinfection, researchers will have to consider the toxicity of the disinfectants and their by-products, the efficacy of each disinfectant in preventing transmission of waterborne infectious disease, and the best methods to control contamination.

EPA research has identified the extent of the trihalomethane contamination problem and, in concert with universities and water utilities, has also determined the effectiveness of various methods to control trihalomethanes in water. The approach to controlling trihalomethanes (THMs) is four pronged: removal of these compounds by treatment, removal of their precursors by treatment, reduction of their subsequent formation by use of alternate disinfectants, and changing the point at which disinfectants are applied. The emphasis of this approach is on the prevention of trihalomethane formation. Utilities are continuing to study the techniques most appropriate to control trihalomethanes, which are now regulated. There is still, however, a lack of clear understanding about the fundamental nature and extent of the chemical reactions that cause the problem in the first place and about the health effects and risks that come from the by-products.

Chlorination of drinking water produces mutagenic activity in test systems. Yet the trihalomethanes and other specifically identified by-products of chlorination account for less than 2% of mutagenic activity of the chlorinated products and by-products of chlorination. Some compounds have been confirmed as carcinogenic. For example, haloacetonitriles identified as by-products of chlorination have had their carcinogenic activity confirmed in mouse skin initiation/promotion studies.

Alternative disinfectants to chlorine are also reactive chemicals and give rise to as yet unidentified by-products that also possess mutagenic activity. Their supposed carcinogenic activity remains to be confirmed. Consequently, no firm conclusion can be drawn as to which disinfectant method is safest. To support a choice among the alternatives, data are being developed to establish: the relative hazards associated with the use of each of the disinfectants and their by-products the efficacy of each disinfectant for controlling waterborne infectious agents and whether any single one is effective against all biological forms.

By 1985, for example, information will be available on disinfection practices. EPA investigators have been evaluating these processes in laboratory and field tests. Other research will characterize and improve treatment technologies including disinfection, microbe filtration, ion exchange, aeration, adsorption, and/or reverse osmosis for the control of organic, inorganic and radionuclide chemicals, chlorinated organics and/or particulates. Pilot programs are used to assess cost effectiveness and feasibility.

EPA research is attempting to identify the specific characteristics, extent and health significance of reaction by-products. Laboratory work will define the extent and character of reactions with aquatic humic materials and the nature of organic halogen and oxidation by-products that are formed. The physical and chemical factors that influence the reaction also will be identified as the first step toward the development of control strategies which may be warranted by health effects data.

Laboratory work to characterize the compounds is now under way. Preliminary treatment data focusing on the amount of organic halogen produced is being collected from bench and pilot studies. Treatment method effectiveness data will be developed later. Should the health effects research indicate a health problem, evaluations will be made at full-scale treatment plants.

Research on health effects will be conducted in parallel with the research to characterize the compounds. EPA has already undertaken the primary role to determine overall health hazards from the use of each alternative disinfectant. A companion research effort is being conducted by the National Toxicology Program to test several individual disinfectants and by-products in lifetime carcinogenesis bioassays. Related health research includes: the demonstration of similar biological effects in samples concentrated from drinking water, the analytical demonstration of parallels between products formed under model conditions and those formed in actual situations, the assessment of hazards of major individual compounds and of the toxicity of the disinfectants themselves (including the in vivo formation of toxic products).

Evaluations of the toxicity of disinfectants will use established techniques in target organ toxicology (including reproductive studies), carcinogenesis and mutagenesis testing. Although preliminary clinical trials have been conducted with these agents in normal human volunteers, the toxicological properties of the disinfectants indicate a need to conduct studies on sensitive human populations, e.g., individuals with compromised thyroid function, before the disinfectants are actually used to treat drinking water.

By-products will be evaluated using a modified tier approach. Screening methods will determine whether significant biological activity results from treating model substrates or actual water samples with alternate disinfectants. These short-term assays will allow fractionation and individual identification of the toxicologically important by-products. The fractions found to be toxic will be tested further to provide data to assess actual risks.

The major products found to have biological activity will be subjected to comprehensive study of their carcinogenic, mutagenic and other toxicological properties. In fact, by 1986 it is expected that the research will have demonstrated extensive qualitative and quantitative applications of bioassay results to estimate human health risk. This methodology will serve as the basis of judging hazards posed by complex mixtures of chemicals as well as by individual compounds.

By 1985, studies will be made of the toxicological properties of the disinfectants and their by-products with natural background organic matter present in source waters. By 1986, additional studies will assess the effects of the disinfectants in the susceptible human volunteers. Also in 1986, studies will evaluate whether the characteristics of the source water must also be considered when choosing a disinfectant for use. Methods being examined include procedures for quantification of viruses and parasites or improved indicator systems.

Issue: What water treatment technologies are applicable to small communities?

Many small communities in America have a difficult time in meeting the drinking water quality levels set forth in the National Interim Primary Drinking Water Regulations (NIPDWR). In a recent survey, the U.S. Government Accounting Office found that 146,000 violations of the NIPDWR for community water supplies had been reported. From the small communities' point of view, the main problems with complying with NIPDWR are the high cost of producing the small volumes of drinking water used by the community and the difficulty in hiring and retaining trained operators for water treatment plants.

EPA's drinking water research program will take a strong role in evaluating cost-effective central treatment technologies. Emphasis of the research will be on evaluating new technology for the ten regulated inorganic contaminants three radionuclides the regulated pesticides (endrin, lindane, methoxychlor, toxaphene, 2,4-D and 2,4,5-TP silvex), and trihalomethanes. This research will also evaluate industry solutions to non-central, or point-of-use treatment for the home as an alternative to central treatment to remove some inorganic as well as organic contaminants. The purpose of this research is to test the effectiveness of treatment methods and to encourage the use of the best of them. Additional consideration will be given to treatment methods that will result in drinking water to meet different quality requirements. EPA's research will also help to evaluate new and improved technologies for removing unregulated inorganics, organics, microorganisms and particulates.

Research is continuing to evaluate the cost and engineering feasibility of specific treatment techniques to remove or control problem inorganic contaminants (such as arsenic, radium and uranium), organic contaminants (including pesticides and chlorinated organic solvents), trihalomethanes, microorganisms and particles. Several evaluations are at pilot or full scale. Bench-scale studies are being done to define variables that govern the effectiveness and efficiency of treatment processes prior to large-scale evaluations. Reports of these findings will be released beginning in 1984 and continuing into 1987.

Issue: What new methods are needed to analyze organic contaminants?

The trihalomethanes, chlorinated pesticides and herbicides regulated by the NIPDWR can be detected, measured and analyzed in drinking water using state-of-the-art analytical methods. Additionally, analytical methods have been developed for the 14 volatile organic chemicals (VOCs) proposed for regulation with maximum contaminant levels for drinking water. Methods have not been developed, however, for many non-volatile compounds such as pentachlorophenol, dinitrophenol, atrazine, simazine, picloram and phthalates which are sometimes found in drinking water.

Analytical methods are not currently available for all of the compounds that might cause problems, but the monitoring research will identify the analytical deficiencies. Research planned over the next few years will investigate analytical methods applicable to a large number of chemicals, including intractable and highly refractory compounds. Analytical methods use advanced technology to detect drinking water contaminants. High-resolution (capillary column) gas chromatography, high-performance (microcolumn) liquid chromatography and gas chromatography/mass spectrometry methods are becoming more widely available. New means to apply these analytical methods are being developed as well. For example, a technique which measures total organic halogen is a reasonable, less expensive and more rapid method for analyzing halogenated VOCs. Similarly, in the effort to detect the 14 VOCs proposed for regulation, new analytical methods have been developed for halogenated solvents and non-halogenated aromatic volatile purgeable compounds, which are indicators of industrial contamination.

Two significant approaches are: adsorption of organics into solid sorbents and subsequent thermal desorption directly into a gas chromatograph or a chromatograph/mass spectrometer, and an extended purge-and-trap system which, as an advanced version of closed-loop stripping, may apply to a wide range of volatile chemicals. Methods will also continue to be developed which use surrogate parameters as indicators of chemicals that are difficult and expensive to detect.

Some of the chemicals requiring possible analytical methods may be identified from other EPA research. For example, risk assessment studies may identify chemicals that pose a health risk and water technology studies may reveal various hazardous or toxic chemicals being discharged to wastewaters or drinking water sources. The application of advanced control technologies may also call into question the applicability of the current means to preserve samples because of possible chemical reactions among the organic contaminants in the samples during storage. The output of the drinking water analytical methods research program is mostly near term to meet impending deadlines of the NIPDWR review.

Issue: How should quality assurance requirements be incorporated into the compliance program?

Semi-annual performance evaluations of laboratories, on-site visits by testing teams and distribution of updated procedure manuals constitute EPA's efforts to assure the quality of data used in drinking water research. In a related program, EPA approves alternative test procedures for national use.

Samples for quality control checks and for performance evaluations to certify laboratories, as required by the Safe Drinking Water Act, are currently available for all of the regulated drinking water contaminants. The EPA drinking water research program produces the samples, documents the concentration levels, establishes sample shelf lives, and distributes them to laboratories that are to be evaluated for performance or are to undergo a certification check. EPA is also responsible for conducting and verifying those evaluations and checks.

To stay current, the research program needs to increase the number of laboratories certified to do quality analyses, particularly private organizations that may have to replace EPA's efforts. The research program also needs to increase the number and types of test parameters used in performance evaluations and to update the procedural manuals for field sampling, microbiological analysis and evaluation of chemical and radiochemical certification.

The quality assurance work is expected to continue for several years. Performance evaluation studies and the distribution of quality control samples will occur each year, as will the development of expanded quality control sample series and reference standards for newly regulated contaminants. Microbiological manuals will be updated in 1984 and 1987.

Plans in the next few years call for EPA to modify and amend the NIPDWR by issuing Maximum Contaminant Levels (MCL) for radionuclides in drinking water. The radionuclides of current concern are radium-228, radon-222 and uranium. Thorium, which is four times more abundant than uranium, should also be studied to determine possible health effects from exposure through drinking water. Other studies need to develop monitoring methods that do not rely solely on gross alpha particle activity in order to monitor water supplies for radium-228, which is a beta emitter. EPA's drinking water research program will develop monitoring methods and evaluate alternative test procedures or methods to determine their precision, accuracy and validity.

The research approach is first to evaluate radionuclide monitoring methods with a single operator and then to validate the methods with multi-laboratory collaborative testing. EPA's researchers will also produce performance evaluation (PE) samples, which are used to assist in laboratory evaluation and laboratory certification. Continual training of laboratory technicians and analysts will help assure future data quality.

Over the next five years, emphasis will be on increasing the sensitivity, precision, accuracy and rapidity of the laboratory methods. Research efforts will also attempt to make the methods simpler and less expensive.

Issue: Are geophysical monitoring techniques applicable to drinking water problems?

One of the major potential threats to drinking water quality is the contamination of ground water. Such contamination can come from waste injection wells. It was estimated in 1979 that about 500,000 municipal, industrial, commercial, agricultural, and domestic wells injected fluids into the ground and that at least 5,000 new injection wells were being constructed each year.

Ground-water contamination can also come from abandoned, poorly constructed or poorly maintained hazardous waste disposal sites. Wastes from disposal sites can leach down into the soils, migrate into the ground water and contaminate water being withdrawn as drinking water.

Monitoring techniques to satisfy legislative requirements and to gain more knowledge about the subsurface environment in general are not sufficiently precise. For example, current monitoring methods cannot track fluid movements from existing injection wells to verify the safety of nearby ground water. To rectify this and other ground-water problems, EPA's drinking water research program has begun to search for existing monitoring technology that may be adapted. One such existing technology is geophysical monitoring developed for mineral resource exploration. Oil and coal companies and hard-rock mining companies have for years used geophysical monitoring technologies to locate promising drilling sites and ore bodies. Other promising technologies include magnetometers, seismographs and resistivity measurement instruments. These technologies may need to be improved or modified for precision, accuracy, simplicity, speed and reliability before they can be used to monitor ground water.

Magnetometers measure the presence of metal objects and other geomagnetic anomalies in the subsurface by emitting electromagnetic energy which, when it strikes the metal object, either induces a current in a detector coil or alters the proton spin of reference material. The sensitivity of these measurements can be sufficient, it is expected, to locate abandoned well casings in the vicinity of proposed injection wells. Seismic reflection monitoring uses mechanically or explosive-produced subsurface pressure waves to map underground features, including ground-water characteristics such as depth and types of soil and rock. Resistivity instruments measure the electrical resistance of soils, which changes in proportion to the amount of water in the soil. Resistivity surveys may be a means to monitor fluid movements from injection wells and to track and map contaminant plumes from waste sites.

EPA will test these technologies in actual contamination situations. Airborne and surface-operated magnetometers will be tested in cooperation with the USGS to locate abandoned wells. This research will determine the best survey patterns to locate well casings based on the sensitivity of the instruments and the magnetic properties of well casings. Resistivity and seismic surveys will also be conducted at existing injection wells.

Issue: Does subsurface biotransformation of pollutants help to protect underground sources of drinking water?

Knowledge of the biotransformation of pollutants in regions of the earth below the root-zone is incomplete, primarily because systematic investigation of the phenomenon was begun only a few years ago. The USGS has produced a small but useful body of literature concerning the biotransformations of industrial wastes injected into deep disposal wells, and petroleum microbiologists have shown that biotransformations can occur deep within the subsurface in petroleum reservoirs. But the microbiology of organisms indigenous to more shallow aquifers containing potable water was ignored until recently, probably because many microbiologists felt that these regions did not receive enough metabolyzable organic carbon to support life.

Recently, some surprising results emerged from a three-site survey carried out by EPA and the National Center for Ground-Water Research. The survey revealed high densities of microbes -- 10^5 to 10^7 per gram of subsurface material -- in shallow water-table aquifers and the associated regions of the unsaturated subsurface environment. Generalizing from these results, it may be true that the total biomass of bacteria in aquifers and associated unsaturated zones is greater than the biomass of bacteria in the rivers and lakes and comparable to the total bacterial biomass of surface soil. By the end of 1983, EPA plans to have developed a set of methods for describing the character and populations of subsurface microorganisms.

The biochemical components of the subsurface microbes are recognizably different from those found in surface habitats. Biotransformation assays reveal that subsurface microbes can degrade several organic pollutants (chlorobenzene, toluene, styrene, bromodichloromethane) that are also degraded by surface organisms. There is preliminary evidence from field studies that the halogenated aliphatic hydrocarbons undergo biotransformation under anaerobic conditions, occasionally resulting in extremely undesirable products such as vinyl chloride. The precise environmental conditions required for these biotransformations are, as yet, very poorly defined.

EPA's primary research role in this area has been to develop techniques to sample the subsurface without contamination from surface materials. To this end, the research will produce a manual for non-drilling monitoring and characterizing techniques, and a document assessing the state of the art for down-hole (in situ) sensing techniques. Both documents will be available in 1984. In 1985, updated manuals will be produced for sampling and monitoring well construction and, in 1986, a manual on tracer technology will be published.

An additional EPA research role is to develop techniques for using uncontaminated samples to construct microcosms for studies on the biotransformation of important organic contaminants. Researchers are studying the numbers, metabolic activity, and biochemical characteristics of the organisms in the same subsurface materials used to construct the microcosms. Researchers supported by EPA were the first to obtain evidence for biotransformation of halogenated aliphatic hydrocarbons under anaerobic conditions. On-going work will test these findings and more precisely define the environmental conditions under which these biotransformations can be expected.

Other major research organizations are conducting related research which is being closely followed by EPA. USGS researchers have conducted some biotransformation studies in support of comprehensive hydrogeologic appraisals at specific waste disposal sites, including industrial deep well disposal operations, municipal wastewater injection sites, and an abandoned wood-creosoting operation. This work has consisted almost exclusively of laboratory studies of organisms obtained from polluted well waters and, for the most part, has not been concerned with aquifers containing potable water.

Recently initiated projects, however, include studies of hazardous wastes in drinking water aquifers. Additional related work has been done by Swiss researchers who have studied the fate in aquifers of a number of important ground-water contaminants, including trichloroethylene and several chlorinated phenols.

The major objectives of EPA's current and future research on biotransformation of pollutants in the subsurface are to identify those biological processes that may occur in various subsurface environments, to determine the influence of subsurface physical and chemical factors on biological activity, and to characterize the biological processes quantitatively. Once this is done, data from the research can be incorporated into solute-transport models which, in turn, can help in the selection of cost-effective regulatory or clean-up strategies. By 1985, it is expected that the research will identify those subsurface conditions which determine whether abiotic or biotic processes dominate pollutant behavior.

Laboratory microcosms are being used to depict the course of biotransformation of organic pollutants under various subsurface conditions, to determine the effect of pollutant concentration on the rate of biotransformation under both aerobic and anaerobic conditions, and to identify the minimum concentration of an organic pollutant that perturbs subsurface microbes and changes biotransformation rates. Work is in progress to evaluate the ability of the microcosms which are now in use to simulate the biotransformation processes at an existing waste disposal site. Later studies will determine requirements for the extrapolation of data from a microcosm study to actual pollution incidents.

A possible benefit of the microcosm work is the identification of a biological characteristic that can be used as an index to predict biotransformation rates. Such an index would greatly reduce the cost and effort required to project the fate of a pollutant. Potential indices include cell density by direct microscopic examination, biomass estimates based on quantities of cellular structural components (such as muramic acid or lipid phosphates) and estimates of metabolic activity (such as adenosine triphosphate content or dehydrogenase activity). Preliminary results indicate that this approach is promising. However, at least ten microcosm studies will be needed to produce sufficient data to identify a suitable index.

Results from this and other research are due in the next few years. Information about the degradation of low-molecular-weight chlorinated hydrocarbons, polynuclear aromatic hydrocarbons, alkylbenzenes, and chlorinated phenols will be available in 1983 and 1984. Data about the effect of pollution concentration on the rate of biotransformation will also be available within the next two years. By 1985, a model will be proposed for use in predicting ground-water quality, at a given point of water withdrawal, that would result from the release of contaminants into the subsurface environment.

Chapter Four
TOXIC SUBSTANCES AND PESTICIDES

TOXIC SUBSTANCES AND PESTICIDES

Outline:

Introduction
Legislative Mandate for Toxic Substances
Legislative Mandate for Pesticides
Background
Major Research Issues

- **Issue:** What monitoring and data handling methods need to be developed?
- **Issue:** What environmental parameters need to be factored into hazard, exposure and risk models?
- **Issue:** What new tests are needed for chemical hazards and risks?
- **Issue:** To what extent do substances of similar chemical structure produce similar health or environmental effects?
- **Issue:** What biological responses are of concern for toxic substances and pesticides?
- **Issue:** Does field information verify pesticide exposure models?
- **Issue:** How can pesticide transport and fate models be improved?
- **Issue:** What environmental measurements should be required for biological pest controls?

INTRODUCTION

Man-made chemicals are pervasive in American society. Some of these chemicals are hazardous to humans, plants or animals. If used with careful controls, these synthetic substances can be extremely beneficial. If used inappropriately, they can be detrimental to humans and to the stability of the environment.

The problem is illustrated by pesticides. By controlling pests, these synthetic chemicals increase agricultural production, lower food prices, and may reduce the likelihood of disease in animals and humans. However, used improperly the same chemicals can be toxic to untargeted plants, animals and humans. These toxic effects may arise at various points in the manufacture, use and disposal of the chemical. By-products and impurities, and the persistence of the chemicals in the environment, may increase the health risk and add to the problems of defining toxicity and risk.

The task of controlling toxic chemicals in general, and pesticides in particular, is twofold: first, to prevent unreasonable risk to human health and the environment, and second, to ensure that the tests required for the control of these substances are as accurate and cost-effective as possible. Decisions about the control of toxic chemicals and pesticides must be based on accurate information about the costs, benefits and risks of each substance. EPA's toxic substances and pesticides research programs are dedicated to maintaining and improving the quality of this information.

The purpose of this chapter is to explain the research needs of EPA's Office of Pesticides and Toxic Substances, to describe the research objectives related to those needs, and to indicate the EPA research activities planned to meet those objectives. In addition, the chapter will describe the current research focus and future trends.

The toxic substances and pesticides research program for fiscal year 1983 is allocated $33.7 million. This total is divided among two subprograms: toxic substances research, $27.2 million, and pesticides research, $6.5 million. The total resources for the toxic substances and pesticides research program are distributed among the major research areas as follows:

environmental processes and effects, 38%; health effects, 35%; monitoring systems and quality assurance, 18%; stratospheric modification and the National Center for Toxicological Research, 5%; engineering and technology, 2%; and scientific assessment, 2%.

LEGISLATIVE MANDATE FOR TOXIC SUBSTANCES

The Toxic Substances Control Act (TSCA) establishs EPA's authority to regulate, if necessary, all commercial chemicals except those uses specifically exempted in the act.

Section 4 of TSCA gives EPA the authority to require manufacturers and/or processors to test their chemicals for health or environmental effects. This authority is selective, applying only to those chemicals for which EPA makes certain findings as to the need for testing. Testing requirements under Section 4 are imposed by rule, each rule specifying not only the chemical to be tested, but also the nature of the required tests. EPA's Office of Toxic Substances is also using negotiated testing agreements to implement Section 4.

Section 5 of TSCA establishes a premanufacture notification process for all new chemicals or significant new uses of existing chemicals. The manufacturers of these chemicals are required to submit information to EPA for review prior to production. Unless EPA finds that the chemical poses an unreasonable risk or demonstrates the need for additional testing, the chemical is placed without restriction on the EPA inventory of existing chemicals.

Sections 6 and 7 of TSCA provide control authority for existing chemicals. Section 6 is general regulatory authority and Section 7 gives EPA special powers to address imminent hazards. Section 8 provides EPA with information-gathering authority. Using these three sections, EPA can limit the production, distribution, disposal or use of chemicals to prevent unreasonable risks to health or the environment.

LEGISLATIVE MANDATE FOR PESTICIDES

EPA's legislative authority to regulate pesticide use comes from the Federal Insecticide, Fungicide and Rodenticide Act (FIFRA) and Sections 180, 193 and 561 of the Federal Food, Drug and Cosmetic Act (FFDCA). FIFRA gives the EPA responsibility for determining the standards for registration of pesticides for legal use in this country. Section 3 of FIFRA provides EPA with the authority to regulate the use of pesticides in a manner which will not result in unreasonable adverse effects to the public health and the environment. Sections 180, 193 and 561 of the FFDCA provide EPA with the authority to set tolerances and exemptions for pesticides in food crops and in animal feed and food additives.

To obtain registration for a pesticide, a manufacturer must first test specific health and safety aspects of the substance using testing guidelines suggested by EPA. Results of these tests are then submitted to EPA, which decides either to register the pesticide for general or restricted use, to request more information from the manufacturer, or to deny or revoke registration. When a pesticide is registered, EPA specifications for it include allowable use, means of production, disposal requirements, crop residue limits, and tolerances in animal feeds and food additives.

The Registration Standards Program involves an intensive review of the data base supporting already registered chemicals. The Special Review Program includes risk/benefit reviews of registered pesticides when there are effects exceeding established criteria for "reasonableness". Special reviews may be launched if such criteria are met or exceeded during development of a Registration Standard, or because such information is made known to EPA.

BACKGROUND

In addition to conducting and supporting research projects, EPA's research program investigates the scientific literature and follows relevant projects of other federal agencies such as the National Institute of Environmental Health Sciences, the National Cancer Institute, the Food and Drug Administration, the National Center for Toxicological Research, and the National Institute for Occupational Safety and Health.

The toxic substances and pesticides research programs are designed to meet specific research objectives in support of EPA's enforcement and regulatory functions. Although the research programs are separate, much of the research being done and many of the scientific questions and issues being addressed are similar. The programs, therefore, are presented together in this **Research Outlook.**

The objectives for toxic substances research are:

- Develop methods and provide quality assurance for TSCA data and analytical activities.
- Develop and validate test methods to assess health and environmental hazards of chemicals.
- Develop and validate methods to predict and monitor human and environmental exposure to chemicals.
- Develop structure-activity fate and effects relationships in support of premanufacturing and new use reviews.

The objectives for pesticides research include:

- Define the environmental and health endpoints for research.
- Develop methods for improved risk assessments.
- Develop and validate test methods to identify health and environmental effects.
- Develop and validate techniques to assess human and environmental exposure.
- Provide quality assurance assistance and support for regional/state laboratories and other FIFRA activities.

The key scientific issues now being studied by EPA to fulfill both sets of objectives are:

- What monitoring and data handling methods need to be developed to meet the requirements of TSCA and FIFRA?
- What environmental parameters need to be factored into mathematical models and what is required to verify that the models are accurate predictors of hazard, exposure and risk?
- What new tests are needed to assess chemical hazards and to evaluate risks of known effects?
- To what extent do substances of similar chemical structure produce similar human health and environmental effects?
- What biological responses are of concern for toxic substances and pesticides?
- Does field information verify pesticide exposure models? If not, to what extent do the models need improvement?
- How can pesticide transport and fate models be refined to gain greater precision?
- What environmental measurements should be required for biological pest controls.

MAJOR RESEARCH ISSUES

Issue: What monitoring and data handling methods need to be developed?

Many existing chemicals that fall under the purview of TSCA are difficult to monitor. Data about them cannot be collected or analyzed with a high degree of confidence because of inadequate methods. As a result, there is a tendency to rely on large safety factors to ensure the protection of the public from poorly defined risks.

With regard to potentially toxic substances, TSCA requires sound and rigorous monitoring methods and data collection and analysis techniques. Such techniques and methods, being developed to meet the mandates of other environmental protection legislation (e.g., the Clean Air Act), may suffice technically for TSCA. However, in some cases development schedules may not be in phase with regulatory needs. Therefore, EPA's toxic substances research program will focus on developing and improving key technical methods.

Method development specific to TSCA needs includes monitoring methods for collecting field data to improve estimates of human exposure, improved collection methods for polar compounds and improved methods for analyzing the large quantities of data gathered.

In addition, research will continue to improve methods for both PCB and bulk asbestos. The PCB research seeks to improve ways to differentiate among the numerous PCB isomers and to develop associated quality assurance reference materials. The asbestos research effort continues to provide quality assurance audits and develops measurement techniques to allow the EPA regulatory offices to assess the effectiveness of asbestos clean-up operations.

The risk assessments mandated by TSCA require exposure assessments which are, of necessity, based primarily on data collected for other purposes. With exposure becoming a more important factor in EPA regulations, research in this area is focused on improved methods for collecting exposure data. In particular, portable monitors and biological tests to document exposure in individuals will be developed for specific chemicals of concern. Methods will be developed, using questionnaires and statistics, to relate individual measurements to larger populations. In addition, field sampling techniques will be developed to monitor exposure pathways, both to provide data and to validate predictive models.

A related research area of growing importance involves improved methods and techniques for handling the great quantities of data generated under TSCA. Research is directed at pattern recognition and other data reduction techniques and at improving computer programs for presenting and relating diverse data sets.

Because implementation of TSCA requires a greater reliance on biological measurements than did previous legislation, quality assurance research will focus on developing laboratory guidelines for biological tests, standardization of biological methods and development of standard reference materials for biological tests. Additional quality assurance work will develop guidelines for validating the predictive models currently being used in the regulatory process.

Issue: What environmental parameters need to be factored into hazard, exposure and risk models?

Mathematical models are used as part of the regulatory process to assess the impact of toxic substances and pesticides on the environment. Effective models share two characteristics. First, they realistically describe the physical and biological components of the environment. Second, they can be used to reasonably predict exposures and hazards of toxic substances to individual species or designated populations.

Mathematical models of the physical environment are used to estimate the movement and concentration of toxic substances in the environment. The models produce estimates of environmental concentrations which are, in turn, used in risk assessment determinations. The problem is that relatively few of the physical models have been validated in the field; their precision and accuracy of prediction need to be defined for specific applications. Field validation may reveal the extent of uncertainty in the model segments that have been exhaustively analyzed and can help to define confidence intervals. Such analysis is key to documenting the reliability and limitations of the mathematical models.

To validate models, current model users will define intended model use and determine the most important components for validation. The resulting prioritized list of research tasks will be submitted to peer review to define the details of research necessary to produce models that will yield reliable and accurate results.

The approach to be taken is first to fine tune a model's simpler components under controlled laboratory conditions and then to move to simulation of the more complex components, also under laboratory conditions. Models will then be validated in the field. One key assumption to be tested is that components that work individually can also work in tandem. Field validation of the integrated components will focus on the applications likely for the model. Verification will include non-steady-state conditions for time and chemical loading factors. A test model will be developed by EPA, subjected to scientific peer review, to review by EPA program officials and to validation and comment. If successfully validated, the method will be formally announced by EPA along with its intended use and limitations. Estimates of a model's precision and accuracy will be part of its description, as will comparison with other models.

Major planned results from this research include a second-generation environmental exposure assessment modeling system (EXAMS) in 1983, screening toxicity prediction models for the estuarine environments, due in 1984, models to predict the concentrations of toxic substances in the air and in terrestrial environments including ground water, due in 1984 and 1986, and models to estimate human exposures to organic chemicals, due in 1985. Results expected from the pesticides research effort include: methods to quantitatively describe sorption kinetics and exchange rates in soils and sediments, and models to predict microbial degradation rates, transformation processes and rate variations for pesticides in aquatic systems, due in 1983, a field validation and general availability of a fate model for orchards, due in 1984, and improvements and field verification of models to estimate exposures and risks in 1985 and 1986.

Issue: What new tests are needed for chemical hazards and risks?

The levels of chemical hazard are measured by tests which use whole organism responses to known concentrations of a chemical substance. EPA establishes methods based upon various statutes to ensure that the tests are accurate, reliable, economical, and scientifically sound. Currently, 96 testing methods have been published. Research is now underway to improve these tests, increase their applicability to other chemical classes, decrease their costs and advance their use in overall hazard assessment. Also, more complex tests are being developed for upper tiers of a given test scheme.

Existing tests are designed to evaluate the responses of single species of organisms to toxic chemicals. The tests are relatively simple and serve as first-tier, screening methods for rapidly evaluating whether chemicals need more complicated testing. Additional tests are needed to measure and evaluate multi-species and system-level impacts of toxic substances and chemical pesticides. Furthermore, methods to evaluate other environmental processes must be added to available test methods, and inter-laboratory comparison (round-robin) testing must be carried out to evaluate test reproducibility and the expected range of error. Subsequent microcosm and field testing of the methodologies will validate these procedures.

Ongoing EPA research and that of other federal agencies including NCI, NCTR, and FDA, will enable EPA to produce a completed spectrum of lower-tier testing schemes. Development of upper-tier test methods will continue.

Among the major planned products of the toxic substances and pesticides research effort are:

o Inter-laboratory comparison of tests using benthic marine organisms for ecological hazard assessments, 1983.
o Short-term assays to define ecological risk associated with sediment-bound toxic chemicals, 1983.
o Use of fish as surrogates for mammals in toxicity studies, 1984.
o Established criteria for judging the usefulness and validity of test results in freshwater, system-level assessments, 1984.
o Guidelines on laboratory-to-field extrapolation of toxic stress on estuarine macro-benthic communities, 1984.
o Data base development and field validation of tests for predicting effects of toxic chemicals in marine systems, 1985.
o Field validation of laboratory-derived, microcosm, bioassay and effects test methods, 1985.
o Test methods for use in defining possible hazards of chemicals for: cardiovascular disease (1984), immune system impairment (1985), mutagenesis (1985), reproduction (1985), neurobehavior (1986), cancer (1986), and liver/kidney impairment and disease (1986).

- o Short-term testing methods for specific neurophysical, neurochemical and neurobehavioral changes to screen for the effects of toxicants, 1986.
- o Assessment methodology for human heritable effects of chemical exposure, 1985.
- o Development and validation of short-term, cost-effective methodology for identifying the teratogenic potential of chemicals in order to support or eliminate the need for extensive animal tests, 1985.
- o Development of methodology for the prediction of potential reproductive toxicity which may be used in determining the need for two-generation animal studies, 1986.

For the pesticides research program, planned products include:

- o Techniques for culturing and maintaining aquatic "indicator" organisms (e.g., fish and invertebrates) used in toxicity testing, 1983.
- o Acute and chronic testing studies to determine critical life-stages of exposure to toxicants and to determine pesticide toxicity (dose) and effects on key species, continuing.
- o Studies to compare laboratory toxicity test results with findings from field studies, continuing.

Issue: To what extent do substances of similar chemical structure produce similar human health and environmental effects?

The results of careful studies on molecular structure and specific activities, or reactivities, indicate that compounds of similar chemical structure may have similar biological properties and effects. This phenomenon is called structure/activity relationship or SAR.

Structure-activity relationship analysis is a key part of EPA's evaluation of new chemicals under the premanufacture notification (PMN) program. Most PMNs are accompanied by little test data on health or environmental effects. As a result, EPA employs SAR analysis to set priorities among PMNs in terms of potential hazard and to build the case for requiring testing under Section 5(e) of TSCA. Similarly, EPA may use SAR analysis to support testing requirements or to guide in the selection of the most appropriate tests for existing chemicals under Section 4 of TSCA.

The SAR approach is an attractive and potentially useful one which may be used to produce rapid, inexpensive, scientifically acceptable data to evaluate the biological effects of chemicals and thus to improve risk assessment. With verified SAR methodology, data collected and validated on one chemical could be applied to another chemical of similar structure. This could eliminate or reduce the time and expense of testing and evaluating the newer chemical for environmental and health dangers. Moreover, SAR data that showed the possibility of chemical properties or effects of concern could be used to optimize the allocation of test and evaluation resources among specific compounds to target the most potentially dangerous substances first.

Other organizations are also involved in SAR research. The Food and Drug Administration continues to investigate SAR, with emphasis on human health effects. EPA is interested in both health effects and environmental fate and effects. A number of industrial and private laboratories, as well as academic institutions, are also developing SAR methodologies.

EPA's research program in verifying SAR began with a review of research done by the FDA, chemical companies and private laboratories. Data on a wide variety of compounds are being collected from these sources and from EPA's research to identify useful correlations and define the applicability and limitations of recognized correlations.

The research has two objectives: to develop a data base of existing information and correlations, and to determine the cause-effect relationships between a chemical's molecular structure and its behavior in the environment. Currently there are some recognized scientific methods that can be applied to determine a compound's environmental fate as it relates to chemical structure. Methods to determine the relationships between environmental effects and structure require further development.

The chemical compounds emphasized in the research effort will be selected from a prioritized list of those chemicals which are most hazardous and most frequently proposed for manufacture. By 1985 the research effort will produce preliminary SAR models for evaluation of environmental fate and toxicity of a number of classes of chemicals in various environmental media. By 1986 EPA will be investigating a system using molecular structure descriptions and combinations to predict genetic and carcinogenic activity in humans. Research will begin to define a set of performance characteristics that compare predictions with defined sets of field data to estimate the models' precision and accuracy.

EPA's research seeks to extend the applicability of SAR use. The results of this work will be applied to assuring that the uses of pesticides and other chemicals are properly controlled.

Major research products planned as part of the SAR effort include:

- Prediction capability of toxicity of 12 classes of chemicals to selected fish species, 1983.
- Development of a model for predicting toxicity of organic compounds to selected marine biota, 1983.
- Provision of an SAR analysis of the S. cerevisiae mitotic recombination data set, 1983.
- Definition of thermodynamic properties of chemicals used to estimate reactivity in the atmosphere, 1984.
- Production of a preliminary model for predicting toxicity to terrestrial plants and animals, 1985.
- Field validation of preliminary SAR models developed with laboratory-derived data, 1985.
- Development of an SAR method using molecular electrostatic interaction potentials as a screen for predicting toxicity, 1985.
- Assessment of genetic activity vs. chemical structure based upon GENE-TOX and similar data sources, 1985.

Issue: What biological responses are of concern for toxic substances and pesticides?

A biological response is a discernable reaction in an organism to exposure to toxicants. This response may be used as an indicator of effects or as a targeted endpoint. For human health, endpoints of concern as indicators of reactions to toxic substances are reasonably well defined. These endpoints include cardiovascular disease, immune system impairment, reproductive dysfunctions, neurobehavioral defects and cancer. One specific new indicator for biological pest controls that use baculoviruses is mammalian immunological effects. Data on this endpoint are currently being developed.

The biological responses for ecosystems, on the other hand, are not yet well defined. This problem arises because environmental toxicology focuses on "populations," and biological complexity increases significantly from an analysis of populations to field studies of ecosystems. Thus, while some specific indicators in single-species environments have been identified by validated tests, there is no accepted means to extrapolate the effects indicated by these responses to the multi-species, complex communities of an ecosystem. Moreover, the ability to predict ecosystem effects without collecting extensive and expensive data does not yet exist. Research is needed not only to identify what the environmental responses should be, but also to determine the biological kinetics associated with species and ecosystem resiliency and recovery.

EPA's research effort is beginning to define quantitative environmental indicators. For toxic materials in general, they will be identified in terms of their commercial significance -- a possible indicator may be retarded growth or degraded quality of commercial crops. Existing data will be analyzed to identify research to quantify responses or, at the minimum, to qualitatively estimate them. Field validations of the estimates will be compared to existing data.

By 1988 a catalog of terrestrial and aquatic environmental responses will be available. If the indicators in the catalog suggest adverse effects from toxic chemicals or pesticides, analysis of the data will indicate whether the biological response quantitatively or qualitatively measures the degree of adverse environmental impact.

Issue: Does field information verify pesticides exposure models?

Sophisticated laboratory models have been developed to determine the fate of pesticides in the environment. The output from these models is being used to predict, in part, the exposures to the ecosystem components and to humans and to assess the subsequent risks from those exposures. Much of the output, however, is not validated with specific field measurement. EPA's pesticide research program will perform the field validation.

The proposed field studies seek to replicate actual pesticide use conditions. Models using pesticide data for crops grown in a variety of circumstances will be validated with field studies. One example is an EPA-developed pesticide orchard ecosystem model (POEM) that predicts the distribution of pesticides in or on trees, grass, broadleaves, litter and soil. POEM will be validated in an orchard in the Northwest.

A cooperative study between EPA and the U.S. Geological Survey in Georgia will gather field data on the migration of pesticides through soil to ground water. The results will be used in evaluating several predictive leaching models. Studies will also be designed for pesticides used against specific pests. A field study using actual mosquito control pesticides of an organophosphate or carbamate base applied to ponds will measure population changes to the pond's non-targeted organisms, as well as brain acetylcholinesterase and pesticide residues in fish, aquatic invertebrates and food. Development of a mosquito pesticide model will be coordinated with a regional mosquito control program in a Midwest metropolitan area.

The approach taken in the research is to use existing data and "targets-of-opportunity" for the validation. One such target of opportunity involves validation of an estuarine exposure model using field data collected from the kepone contamination of the James River and estuary.

Information from this research will help in the evaluation of data submitted by pesticide manufacturers for EPA registration decisions as well as in the confirmation of limits specified as part of the labeling requirements. In the long run, field-validated models are expected to improve future EPA pesticide decisions by making them more timely, cost-effective, accurate and credible.

Issue: How can pesticide transport and fate models be improved?

Mathematical models are used to assist in prediction of pesticide transport, fate and exposure. Currently, the models for exposure and fate are being worked on to improve the precision and reliability of their predictions of environmental concentrations of pesticides and toxic substances. Subsequently, these models will be validated in the field. At present, improvements are being made along several lines, including integration of single-medium models into multi-media models, development of models to predict concentrations when source input varies with time, and validation of existing models in microcosms and field ecosystems.

Improvement of the mathematical models is an exacting task, due to their complexity. The models are made up of components that represent conditions in the field. The hazard component identifies and measures potential adverse effects, and is derived from biological analyses and stated in biological terms. The exposure component is described in terms of pesticide concentrations in various media. These components must be integrated in a way that allows the model to serve as a useful tool in assessment of environmental risks.

EPA's research seeks to improve the mathematical basis for determining environmental risks. Initial work will refine the environmental exposure assessment models to fit more closely into the risk framework. The output will be an improved mathematical model for more accurate estimates of a pesticide's impacts.

Much of the effort will involve a careful review and screening of data that is available through the pesticide registration process. Researchers will also review data from specific projects, such as one which will take a census of terrestrial non-target organisms at a pesticide spray site. Other data, such as data on reproductive dysfunctions in humans and other species, will also be studied.

Issue: What environmental measurements should be required for biological pest controls?

Within the past few years an increasing interest has developed in the use of biological control agents (BCAs) to control pests. Over the last five years, the number of EPA-registered BCAs has increased three-fold. The BCAs consist of two distinct categories, biochemical pest control agents and microbial pest control agents. The former are biologically derived chemicals (e.g., hormones and pheromones) and the latter are living microscopic organisms. The living organisms currently registered for use include bacteria, fungi, protozoa and viruses. These microorganisms are known to attack targeted pests but their transport, persistence and fate in the environment and their effects on non-target species are not clearly understood.

The USDA and public and private institutions are currently conducting research on BCAs. Their research emphasis is on development of new agents, efficacy testing and control of target pests. Environmental research is needed to evaluate problems associated with non-target organisms. In response to the EPA's regulatory needs, the pesticide research program will investigate and evaluate hazard data to determine effects from microbial BCAs and from some of the biochemicals (excluding pheromones and hormones) in estuarine, freshwater and terrestrial ecosystems.

The hazard research will include a broad range of investigations. To determine the infectivity, pathogenicity or toxicity of biological control agents in the different media, exposed animals will be observed for behavioral effects. Necropsies will be performed and tissue samples will be subjected to histological, biochemical and genetic analyses to detect the fate and possible effects of the agent in non-target organisms. For the freshwater analysis, the control agent Bacillus thuringiensis will be used to measure exposure concentrations from suspension in the water and from diet and injection. The range of hosts attacked by the microorganism and its stability and persistence will be determined. The work is intended to determine if test data accurately predict the field data.

Major planned research products include:

- Determination in the terrestrial environment of the scope of the effects already known to be caused by BCAs, 1983.
- Development and testing of selected tier 1 protocols for estimating hazards to non-target terrestrial species. Microbial agents will be studied with emphasis on dosing regimes, appropriate non-target endpoints, and survival and persistence of BCAs in the environment, 1984.
- In situ testing of Bacillus thuringiensis with non-target freshwater organisms under field conditions, 1985.
- Laboratory exposure studies using aquatic animals (estuarine) and insect viruses, 1984.

Chapter Five
AIR

AIR

Outline:

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Legislative Mandate
Background
Major Research Issues

- **Issue:** How do people sensitive to air pollutants respond to those pollutants?
- **Issue:** What monitoring and measurement methods are needed to detect and analyze air pollutants??
- **Issue:** What models best describe pollutant transport and transformation?
- **Issue:** How can air quality models reflect complex terrain conditions?
- **Issue:** Can sources of pollution be identified by the unique properties ("fingerprints") of their pollutants?
- **Issue:** What are the health effects from exposure to combinations of pollutants?
- **Issue:** What is the cost of damage to crops from air pollution?
- **Issue:** What are the most effective emissions reduction technologies for volatile organic compounds, nitrogen oxides and other air pollutants?

INTRODUCTION

There are four major air pollution research programs at EPA.

The **gases and particles** program is concerned with the health and environmental impact of sulfur oxides, particles and lead.

The **oxidants** program studies nitrogen oxides, ozone and ozone precursors, which are either directly emitted or formed as a result of atmospheric chemical reactions. Volatile organic compounds (VOC) are an important subset of these precursor chemicals.

The **hazardous air pollutants** program studies pollutants listed by EPA as hazardous and investigates others which may require regulation. After screening approximately 600 high-volume production chemicals, EPA's Office of Air Quality Planning and Standards has identified 37 compounds as being of high priority for more intense investigation. Research during the next two years will assess the health risks of these chemicals and help to determine the need for further investigation.

The **mobile sources** program produces scientific information needed for assessing the impacts of vehicular emissions. Major pollutants of interest are carbon monoxide (CO), diesel particles and unregulated organic emissions.

The air pollution research program for fiscal year 1983 is allocated a total of $59.4 million. This total is divided among four subprograms: gases and particles, $31.9 million; oxidants, $13.1 million; hazardous air pollutants, $8.6 million; and mobile sources, $5.8 million.

The total resources for the air pollution research program are distributed among the research disciplines as follows: environmental processes and effects, 31%; health effects, 27%; monitoring systems and quality assurance, 21%; engineering and technology, 15%; and scientific assessment, 6%.

LEGISLATIVE MANDATE

The Clean Air Act (CAA), as amended in 1977, gives EPA the authority to set minimum standards for air quality. State and local governments are responsible for preventing and controlling pollution sufficiently to attain those standards. EPA's research role under CAA is to conduct research and development programs to acquire the information needed to support both defensible standards and the air pollution regulations necessary to attain them.

BACKGROUND

To meet CAA requirements, EPA's air pollution research programs address two major tasks -- gathering data on the currently regulated air pollutants in order to revise standards on a periodic basis, and compiling data on unregulated pollutants to determine whether potential health and environmental risks may warrant future standards. In the first case, the research refines and extends existing findings. In the second, the research establishes and tests hypotheses. Data derived from both efforts will support the National Ambient Air Quality Standards (NAAQS), the New Source Performance Standards (NSPS), the National Emissions Standards for Hazardous Air Pollutants (NESHAPS), the Prevention of Significant Deterioration (PSD) increments and mobile source standards.

The results of research on certain air pollutants are compiled in "criteria documents" which are required by section 108 of the CAA and which provide the scientific criteria upon which many regulatory decisions are based. Currently, criteria documents have been published for the pollutants regulated by NAAQS under Section 109 of the CAA. These pollutants are ozone, nitrogen dioxide, sulfur oxides, carbon monoxide, total suspended particulate matter, lead and hydrocarbons -- the "criteria pollutants."

Further research on criteria pollutants is performed to refine the knowledge base underlying the standards. For example, questions may include: Should the standards be higher or lower? Should different descriptive units for pollutants be devised (e.g., particles 10 microns and under)?

Research into hazardous air pollutants (those regulated under section 112 of the CAA) asks such fundamental questions as: What pollutants are of concern? How dangerous are they? In what concentrations? What are actual human exposures to these pollutants? Results from this research are published in health assessment documents.

Major themes cut across the air pollution research programs and the issues associated with them. For example, ambient air concentrations of a pollutant at a fixed point may not realistically represent the actual exposure that will determine adverse health effects.

For some pollutants, it is now possible to measure directly an individual's total exposure, including exposure at work or at home. Such measurements will significantly improve EPA's knowledge of actual 24-hour exposure, the spatial representativeness and temporal variability of ambient concentrations and, consequently, estimates of actual health risks.

Research is needed, however, to develop methods for more realistically determining exposure to other pollutants. For example, little information is available about hazardous air pollutants, their concentrations and distribution. Research is now attempting to resolve both the new and the long-standing arguments about estimating cancer risks, evaluating mutagenic hazards, determining effects to reproductive systems and estimating the potency of toxic pollutants. This difficult work is further confounded by the uncertainties associated with extrapolating from data on animals to prediction of effects in humans.

Currently, hazard assessment documents are being prepared on 37 potentially hazardous air pollutants. In addition, determining the potential interactions of these pollutants to form products of greater or lesser toxicity remains a major research challenge. However, one of the problems with field measurements is that, in many cases, measurement technology is inadequate to detect and measure such pollutants in ambient air. Technologies for making measurements in the ambient environment are now being modified or developed, especially for technologies for measuring organic compounds found in urban atmospheres.

Air pollution may pose greater risks to the health of certain more susceptible groups of people than to the remainder of the population. Research is looking increasingly at populations at presumed greater risk. Similarly, health studies using test animals now concentrate on chronic, long-term, low-dose exposures. The lower doses often portray more accurately the pollutant levels seen in the environment. Such long-term, low-dose health research may help to determine if linear or non-linear dose-response curves more accurately estimate the probability of human health impairment from exposure to low doses of air pollutants.

Other air pollution research will improve the scientific basis of models, validate models in the field and improve laboratory methods to refine the models. The models range from atmospheric transport, transformation, diffusion and deposition models, to biological tests that can be used to determine t presence of certain compounds and to scre compounds for potential toxicity. Once these mode are developed, they will be tested for accuracy.

The major research issues responding to tl problems mentioned above are:

- How do people sensitive to air pollutants respoi to those pollutants?
- What monitoring techniques and measureme methods are needed to detect and analyze air pollutan and/or predict actual population exposure?
- What air quality models best describe tl regional, mesoscale and urban scale transport ar transformation of pollutants?
- How can air quality models reflect the transpo and diffusion of pollutants in complex terrains?
- Can sources of pollution be identified by tl unique properties ("fingerprints") of their pollutants?
- What are the health effects from exposure combinations of pollutants?
- What is the cost of damage to crops from a pollution?
- What are the most effective emissions reductic technologies for volatile organic compounds, nitroge oxides and other air pollutants?

MAJOR RESEARCH ISSUES

Issue: How do people sensitive to air pollutants respond to those pollutants?

Health responses of members of the populatic most sensitive to air pollution exposures need to b determined to assure these people an adequate level c protection. Among the groups identified as sensitiv are the elderly, asthmatics, those with chroni obstructive lung disease (e.g., emphysema), persor with coronary vascular disease and children.

EPA's air pollution research programs are buildin upon a data base derived from air pollutant exposure: The existing data base for effects in healthy peopl demonstrates that some persons exposed to variou pollutants exhibited exaggerated responses such a increased sensitivity to bronchoconstrictors an increased airway resistance. Such responses have bee seen either from constant or intermittent exposure t low levels of pollutants over a period of time or fror low levels of exposure with repeated higher peak: Studies previously done by other investigators need t be replicated, and further characterization is needed o effects observed in response to various exposures ove long time periods. Other studies are needed of immediate responses to short-term exposures.

The EPA's research will include epidemiological, clinical and animal studies. The clinical studies will use volunteer human subjects exposed to pollutants in EPA's clinical exposure facility. These persons are exposed, both at rest and while exercising, to pollutants at concentrations bracketing ambient levels. All exposures are acute (short-term) exposures. Subjects will be tested before, during, and after exposure to determine pulmonary function performance, effects on biochemical parameters, and effects on peripheral lymphocytes as an index of immune function.

Normal, healthy individuals of both sexes and several races are being tested. In addition, other groups of people suspected to be susceptible will be exposed to low levels of ozone, NO_2, SO_2 and fine particle aerosols alone and in combination and tested to characterize thresholds of effects if possible. Asthmatics will be studied, using ozone, nitrogen dioxide and sulfur dioxide both alone and in combination with aerosols in tests designed to model ambient conditions. Persons with chronic obstructive lung diseases will be studied using the same pollutants. Persons with pre-existing conditions, enzyme deficiencies such as alpha-1-antitrypsin globulin deficiency, for example, which may predispose them to increased pulmonary responses, will be also studied. In addition, non-invasive methods using a gamma camera to measure ventricular wall motion can be used to monitor the heart. Such methods will be used to study the effects of carbon monoxide on persons with existing coronary artery disease prior to the onset of clinical symptoms such as angina.

Animal tests are investigating both the increased susceptibility to respiratory infections and development of arteriosclerosis to determine if they are influenced or caused by exposures to air pollutants. Studies will be performed on both healthy rodents and those treated to simulate conditions such as asthma or emphysema using long-term (chronic) exposure regimens.

Additional studies will examine differences in sensitivity among various species of small mammals. These results will be useful for extrapolating effects in animals to those predicted for humans, especially effects from long-term exposures or exposures to higher concentrations of pollutants. This is true because by pointing out common responses or different responses in different species and correlating them to known differences between species it should be possible to better predict human responses based on knowledge of human physiology.

Data on chronic pulmonary, pathological and immunological effects of ammonium sulfate and sulfur dioxide on normal animals and animals with impaired respiratory functions will be available in 1987. Results will contribute to revision of the particulate matter standard. In 1987, data will also be provided on respiratory, morphological, immunological and metabolic effects of NO_2 exposure in animals treated to simulate pollution-sensitive human groups.

Further studies will evaluate lead exposure absorption/retention relationships in sensitive populations. Previous findings indicated effects at lower exposure levels than expected. Additional data on the sensitivity of neurological, behavioral and other health factors in children exposed to low levels of lead will be available in 1986.

Research will also provide data on physiological, biochemical and immunological responses to exposure to single and combined gases and particles in normal populations and those in sensitive population subgroups. Additional studies will analyze major urban particulate pollutants (sulfuric acid and ammonium compound aerosols) alone and in combination with ozone, nitrogen dioxide and sulfur dioxide. Results of this work will be available in 1987.

Issue: What monitoring and measurement methods are needed to detect and analyze air pollutants?

Effective modeling, control, and regulation of air pollution depend on rapid and precise methods to measure air pollutant concentrations in both the ambient atmosphere and from specific pollutant sources. This means that an underlying theme of EPA's monitoring research is the development of new measurement methods and of quality assurance programs to ensure that methods currently in use are reliable.

In addition to working to improve site monitors, EPA research will develop non-invasive monitors to gather physiologic data while collecting exposure data. These monitors will be miniaturized for use in field studies to gather accurate data under actual ambient conditions.

For hazardous air pollutants, monitoring technologies and measurement methods are needed to determine precisely the composition of the air and to help to identify those air pollution components that represent a significant health risk. Current collection instruments were not designed to measure these compounds. One major research goal is to develop and deploy monitoring devices to determine if there are pollutants in the air which are, or may be, hazardous. Protocols for the new technology must be developed, field-tested and verified. Most existing methods to monitor hazardous air pollutants employ polymer collection capsules in conjunction with a gas chromatograph (GC) and mass spectrometer (MS). However, some compounds known to be biologically active cannot be collected with the current polymer capsules; new polymers are being investigated to collect the potentially toxic compounds.

EPA recently sponsored the development of a new technology to supplement the GC/MS measurement process: the tunable atomic-line molecular spectrum (TALMS) device. TALMS uses magnetic field excitation to identify compounds. EPA research is currently sponsoring development of a library of spectra for use in identifying compounds.

EPA's research approach to the hazardous air pollutant problem is to take measurements with state-of-the-art equipment while simultaneously developing, testing, refining and verifying new technology. EPA is establishing a regional monitoring center that can perform the sophisticated analyses necessary to detect hazardous air pollutants. The center will also act as the contact point for new stationary or mobile measurement technology.

As the new monitoring and measuring technologies are developed, they will be used for identifying, screening and characterizing hazardous atmospheric pollutants. Emphasis of this research will be on quantifying the atmospheric transport and transformation processes (i.e., chemical reactions and dispersion) that govern the ambient concentration distributions of primary and secondary (derivative) hazardous air pollutants, and on determining the effects environmental processes have on the frequency of occurrence, ambient concentration ranges and patterns of variability observed for hazardous air pollutants.

Similar to the proposed change in the particle standard, there may be a change in the way of calculating personal exposures to hazardous air pollutants. Currently, exposures are estimated using data on emissions and concentrations of the pollutants in the ambient atmosphere. However, total exposures based on actual 24-hour personal exposures may differ from those estimated from the ambient concentrations.

For measuring personal exposures, EPA is developing new methods to work in concert with the new or modified technology for measuring ambient exposures. The results, which may be definitive within the next half decade, will help to determine the appropriateness of the current regulations for the seven listed and four regulated hazardous air pollutants as well as the potential need for regulations for other pollutants. The research program for hazardous air pollutants is expected to gain increasing emphasis during the next few years.

Mobile sources research seeks to determine the extent of human exposures to mobile-source pollutants such as CO, NO_2, diesel particles and unregulated organic emissions. Continuous, real-time personal monitors are presently being used to measure CO concentrations. NO_2 badges sensitive enough to provide data on exposures at ambient concentrations have been developed. Portable devices capable of collecting airborne particles and gases for laboratory study have also been developed. Measurement and analytical procedures for unregulated pollutants, however, need to be refined or developed.

Refinement of analytical procedures that apply to a variety of unregulated pollutants is needed in order to be able to use the procedures for analyzing priority pollutants. Furthermore, development of the analytical procedures is needed for measuring pollutants that are not completely characterized and that pose a potential carcinogenic threat, e.g., organics adsorbed on diesel particles. Research work is attempting to develop bioassay tests as an analytical procedure applicable to emissions from various fuels and fuel additives. In addition to the evaluation of pollutants from current vehicles, these procedures will be needed to identify and assess the health effects of new pollutants from changing fuels and engine technologies.

Research for studying human exposures to CO from mobile sources will be emphasized. Even though nationwide CO emissions have been decreasing, the relationship between vehicle emission rates and actual CO exposures needs to be more precisely determined. By developing a reliable predictive method for determining population exposure profiles in urban areas, CO exposures can be determined and exposures to other mobile-source-generated pollutants can be inferred using the CO data as a surrogate. The most critical portion of the determination of these exposure profiles is the development of sampling methods that can adequately characterize CO levels in important microenvironments.

CO exposure research will also determine whether existing, fixed, in-place monitoring sites for measuring air pollutant ambient concentrations are sufficiently representative of actual CO exposure concentrations. Studies, for example, have shown that curbside measurements vary significantly from sites at slightly different distances from, and heights above, the roadways.

The exposure data can be used to: (1) assess better the health risk of CO to the population, (2) provide a basis for improving the siting of existing monitoring stations, and (3) validate existing exposure models. This validation is particularly important. Field data are needed to further validate estimates used in establishing the National Ambient Air Quality Standard for CO. Those estimates were statistical approximations of the percent of the population exposed to various CO concentrations; actual exposure data are essential for determining whether future emission standards or air quality standards should be relaxed or made more stringent. Exposure models field-validated for CO will be important for other mobile source pollutants as well. As the first statistically representative data base on human exposures for a criteria air pollutant, it will serve as the research benchmark for data bases to be developed for the other mobile-source air pollutants.

The research approach is to develop a data base collected by volunteers who will carry portable carbon monoxide monitors developed by EPA. The monitors are miniature (about the size of a small camera), accurate, reliable and durable. By choosing a cross-section of the population, correlations made between exposures and urban-scale activities can be used as scientific estimates of realistic exposures to pollutants from mobile sources.

Data from the personal monitors will also be used to validate and improve existing computerized human exposure models such as the SHAPE (Simulation of Human Air Pollution Exposure) model. Such models are used to assess the impacts, in terms of exposure, of changes in emissions and activities.

To assess the proper level of control of particles from diesels, information is needed on projected exposures of populations to diesel particles and the long-term health effects from the exposures. Health effects studies are being completed and risk assessments for diesel emissions will be completed in 1983. Risk assessments need to be developed for unregulated mobile source emissions that pose a potential carcinogenic threat, e.g., nitrosamines, formaldehyde and dioxins.

In general, most toxic air pollutants pose problems near to their sources but not over an entire urban area. This is also true of some criteria pollutants. In the mobile sources research program, there is a continuing effort to determine emission rates for many of these pollutants. Such source studies of emissions may provide important input into determining the cost effectiveness of alternative emissions reduction strategies.

For gasoline-fueled cars and light-duty trucks, emissions controls are relatively mature. For these sources, research focuses on developing more precise emissions inventories for volatile organic compounds under different driving conditions. Such information is important for maintaining air quality standards. For other vehicles -- especially heavy-duty trucks and buses -- research will aim at determining the impacts on air quality and human health of alternative emissions reduction scenarios.

The oxidants program will develop measuring methods to help determine the reactivity of air pollutants and the photochemical formation of smog. Emphasis of the program will be on refining existing monitoring technology and quality assurance.

Issue: What models best describe pollutant transport and transformation?

When pollutants are emitted into the atmosphere, they often undergo chemical and photochemical reactions that change the initial pollutants into a range of different compounds. To predict this phenomenon requires that chemical process equations (e.g., for reaction rates) and physical process algorithms (e.g., for dispersion) be integrated into one model. Regional transport and transformation models are being developed for sulfur dioxide, sulfates, particles, ozone, nitrogen dioxide and nitrates including natural emissions of hydrocarbons. The models will provide information on how upwind pollutant sources affect downwind urban areas. This information will be key to developing effective pollution control plans.

The chemistry portions of the regional-scale models are now sufficient to describe some atmospheric reactions. Field studies will be conducted to verify calculations that describe the formation of sulfates from SO_2, the formation of particles, and the reactions that produce ozone.

Not as well developed, however, are the physical algorithms. The traditional approach to such modeling was based on Lagrangian models which are point-source and area-source algorithms. The Lagrangian method describes the motion of air parcels by specifying a conceptual "parcel or volume of air" and tracing its motion over time. These methods assume linear chemistry. That is, they assume that the rate of change in the concentration of a given pollutant is directly proportional to the local concentration of that pollutant. Such methods do not work well when the reaction rate for the pollutant of interest is affected by other factors (e.g., other pollutants) and is, therefore, non-linear.

Eulerian (fixed coordinate) methods of describing air transport will work much better for EPA's regional photochemical transport model. Eulerian methods describe the motion of air by specifying the air's density and velocity at a grid of points in space at a particular time. The Eulerian methods can include the non-linear chemical calculations needed to predict the downstream reactions that form ozone, sulfates and nitrates. The methods also are applicable to long-range, or regional, transport. EPA's research program will develop the Eulerian framework of the models and will integrate it with the chemistry modules.

At the same time, data will be collected to verify dispersion coefficients interpolated from earlier empirical, limited-situation studies. This verification is necessary because the earlier studies were so limited that generalizations may be inaccurate; also, meteorological parameters work best under stable weather conditions and are less accurate for unstable (strongly convective) conditions.

Model development and verification will depend upon data collected during the Northeast Regional Oxidant Study (NEROS)/Persistent Elevated Pollution Episodes (PEPE) program. The regional-scale model will be tested and refined using this field data. A few European countries have expressed interest in using the models and adapting them with their data base.

The regional photochemical model will be a reactive model. That is, it will be capable of handling a number of different complex chemical reaction mechanisms for ozone and particulate matter. The model's 1983 version will address only ozone chemistry. Following that, the model will be developed further to include reactions of SO_2 to sulfate, including liquid-phase reactions. At a later date, nitrate chemistry will be added to the model. A field-evaluated model should be available in 1986.

Urban-scale models will also be developed. The urban-scale models that predict the concentrations of photochemical oxidants in urban air are of two completely different types. One urban photochemical model is based on the empirical kinetic modeling approach (EKMA), much of which is derived from smog-chamber studies. By specifying amounts of hydrocarbons and NO/NO_2 in the urban atmosphere, the EKMA will estimate the level of air pollution controls needed to achieve the ozone air quality standards.

The other type of models -- air quality simulation models for urban photochemicals and particles -- not only provide estimates of concentrations, they also predict the time-varying rate of transformation and dispersion. These models use more advanced chemistry and meteorology than does the empirical model. Most of the research to date has focused on developing and validating first-generation air quality simulation models. The models were tested against a comprehensive air quality and emissions data base obtained through a five-year regional air pollution study conducted in the St. Louis area during the mid 1970's.

EPA's research program is refining both of the modeling approaches. Comparisons of several methods to predict atmospheric chemical reactions showed large discrepancies when existing ozone and NO_x predictive models were run with low HC/NO_x ratios, suggesting that current chemistry submodules may result in erroneous ozone predictions and could introduce errors when used in either the EKMA or air quality simulation models.

To resolve these problems, EPA will conduct indoor and outdoor smog chamber studies, and the data obtained will be used to develop improved chemical submodels of photochemical smog formation. Indoor smog chambers will be used to investigate the photochemical reactions of aromatic hydrocarbons and their oxidation products. Outdoor chamber studies of synthetic volatile organic compounds (VOC), and NO and NO_2 mixtures will investigate the effects of hydrocarbon composition changes on the formation of O_3 and other oxidants. Multi-day irradiations of complex VOC/NO_x mixtures will assess the oxidant-forming potential of "spent" air masses and provide the necessary data for use in a regional oxidant model.

This research will produce chemical kinetic data for use in either EKMA or air quality simulation models and a validated O_3 and NO_2 chemical module in EKMA.

An evaluation of EKMA models using improved O_3 chemistry will be available in 1984. Another significant research output will provide the EPA regulatory office with regional photochemical modeling results based on target emission reduction strategies provided by the Office of Air Quality Planning and Standards. These results will be available in 1986.

At present, sulfate is the only chemical species that will be modeled explicitly. The chemical composition of other particles will be addressed as regulations require.

Research will also lead to validated models which predict one-hour, 24-hour, and yearly average values for urban particulates and the contribution to these values of plumes from large sources at mesoscale distances (0-300 km). An operator's manual will be produced for using the Particulate Episodic Model (PEM) and the point-area-line model in urban situations. An improved urban and mesoscale particulate model will be produced for state and local governments and industry for use in SIP revision based upon the proposed new particulate standards.

Issue: How can air quality models reflect complex terrain conditions?

The Clean Air Act Amendments of 1977 require EPA to specify the use of dispersion models pertinent to prevention of significant deterioration and to attainment of National Ambient Air Quality Standards (NAAQS). However, no adequate model has yet been developed which adequately describes dispersion in complex terrains.

EPA research will develop such modeling capabilities. Initial model development will use field measurement data and results from the EPA Fluid Modeling Facility (FMF) to provide modifications to models currently used in the regulatory process. Concurrently, atmospheric dispersion models will be improved. Field research will include tracer studies over moderately-sized terrain obstacles and a full-scale plume study at an existing power plant in complex terrain. These studies will provide data for evaluating the performance of dispersion models under conditions that cannot be adequately simulated in the FMF.

Subsequent research will evaluate the feasibilities of transferring the models to settings of increased topographical complexity, applying the models during neutral or unstable conditions, and projecting the calculated one-hour concentration to three- and/or 24-

hour average concentrations. Coordination and data exchange will be maintained with similar studies being performed by the Department of Energy and the Electric Power Research Institute.

If the development effort is successful, an evaluated complex terrain model, including a user's guide, will be published in 1985.

Issue: Can sources of pollution be identified by the unique properties ("fingerprints") of their pollutants?

Air pollution samplers in current use can detect, identify and measure the amounts of different airborne compounds that are deposited on the collection grids; the samplers and analytical procedures used cannot identify the sources of the compounds. Now, technology and procedures are being developed to identify the sources of pollutants. The identification is based upon unique chemical signatures of the collected compounds. The concept is called source apportionment.

Source apportionment works by analyzing collected particles with X-ray diffraction, ion chromatography, neutron activation, scanning electron microscopy and other advanced chemical analysis techniques. If the particles in question have the same unique features characteristic of particles found only at certain sources, then the sources of the particles in quertion can be identified. Currently, the methods are sufficiently advanced to be able to identify particles emitted by certain industries but not from any one specific plant within a group of similar industries. For example, particles from quench towers of steel mills have unique chemical signatures, but the methods cannot tell which quench tower produced a certain particle. At present, source apportionment methods are limited by scant emissions data for determining industrial source signatures. Both collecting the requisite emissions data and verifying the chemical analyses and signature matching methods are important parts of this EPA research effort.

Source apportionment cannot, by itself, be used to predict air pollution concentrations. By integrating the apportionment data with urban particulate dispersion models, however, a hybrid model may be able to identify sources or, as the case may be, to predict pollutant types and concentrations at given urban areas under differing conditions. In 1984, EPA will use data collected in Philadelphia to develop such a hybrid model. The immediate goal of the research is to develop and test a comprehensive receptor model for apportioning particulate mass to components from emissions sources.

Issue: What are the health effects from exposures to combinations of pollutants?

In breathing the air, people are often exposed to a predominant single pollutant, but at other times they may be exposed to a mixture of compounds, some of which may be harmless, others hazardous. Health effects research, therefore, is expanding its scope to consider multi-agent exposures including potential synergistic or antagonistic effects in addition to single-pollutant effects. Depending on the findings, it may be more appropriate to consider regulation of combinations of pollutants.

EPA has almost completed single-pollutant clinical research on non-sensitive populations, and emphasis for studies on normal subjects is being shifted to multi-agent studies.

The research is being conducted simultaneously with exposure assessment studies so that health risks can be better defined; however, because the exposures are yet to be determined, in many cases, the effects research does not yet replicate actual ambient conditions. In lieu of that approach, the effects work will continue to expose volunteers and animals to single individual pollutants (e.g., O_3, NO_2, SO_2, or particle aerosols) and then to the pollutants together in various ratios.

As exposure assessments produce results more representative of actual population exposures, attempts will be made to re-design multi-agent clinical and animal experiments for exposure to air pollution mixtures more characteristic of ambient conditions. (There will probably not be a direct one-to-one correspondence of data from this research with epidemiological studies due to the fact that exposure conditions for epidemiological studies cannot be controlled as can the laboratory work. Nevertheless, the object of these studies is to make such correlations as meaningful as possible.)

A multi-year epidemiology study to determine the health effects of fine particles will be considered following analysis of a problem-definition study by the University of Pittsburgh Center.

Issue: What is the cost of damage to crops from air pollution?

Reduced yields of crops and forest species have been observed as a result of air pollution. These reductions are known to adversely affect wildlife habitats and human welfare, but the extent of the effects from lost crop and forest productivity have not yet been quantified. EPA has initiated a high priority research program to measure the economic losses from air pollution, with its primary focus on agricultural productivity.

The research receives considerable involvement from concerned state and local governments, several federal agencies and departments and from non-government research organizations. The research will assess the economics of ozone pollution so that the benefits of air pollution control to crop productivity can be evaluated. Data for the research will come from the National Crop Loss Assessment Network (NCLAN), a national program begun by EPA in 1980.

Since ozone is believed to cause the greatest damage to vegetation, the program will continue to evaluate the impacts of ozone pollution through field research conducted at six regional sites. Crop cultivars typical of a region are exposed to ozone concentrations that span the range of air quality conditions and to a background level that provides an experimental control. Open-top chambers are used in this research, because they are the most thoroughly tested field exposure systems and permit the best control of pollutant concentrations under field conditions.

Results from field investigations will form the basis for the construction of dose-response functions, which relate crop yield effects with various concentrations of ozone. Various types of mathematical regression relationships are being formulated, including a linear approach and a more complex relationship which assumes a threshold concentration. Dose-response information will be integrated with crop yield data and ozone air quality estimates gathered from counties across the United States. In 1984, this information will be used to provide a national assessment of the economic impacts of ozone on the productivity of major crops. Field research is planned to cover about 90% of the crop acreage in the United States.

Research is also planned to quantify the role of soil moisture as an influencing factor in the response of crops to ozone and to evaluate the effects of high level episodes and of low-level chronic conditions. Since these factors are highly important in the response of crops to ozone, they will be evaluated to provide a more quantitative economic assessment.

Issue: What are the most effective emissions reduction technologies for volatile organic compounds, nitrogen oxides and other air pollutants?

Control technologies either remove air pollutants or reduce their formation by process modifications. At present, engineering knowledge is available to provide the necessary technologies, but capital outlays for air-pollution control are significant burdens to many industries. Thus the determination of the least-cost option for controlling air pollution is an urgent goal for ensuring a clean environment and helping to maintain a strong national economy.

Priorities for this research are shifting to focus on volatile organic compounds, including those designated as hazardous. Emphasis on conventional pollutants (sulfur oxides, nitrogen oxides and particles) is declining. In addition, large-scale demonstrations of emissions reduction technologies are being phased out in favor of less costly fundamental studies, pilot and prototype testing and evaluation, and technology transfer.

For the oxidants, research will be initiated to determine the least-cost control alternatives for volatile organic compounds (VOCs) and nitrogen oxides (NO and NO_2), which are the major precursors of oxidants such as ozone.

In widespread areas of the country, VOCs are a major cause of the non-attainment of the NAAQS for ozone. Scientifically valid data bases, methodologies, models and control technologies needed to control VOCs will be provided by EPA's research to regulatory decision makers; enforcement officials; state, regional and local officials; and the regulated community. Control technology such as industrial flares, capture systems, carbon adsorption, catalytic oxidation, and thermal oxidation will be assessed to establish performance standards for new and existing sources of VOCs. New source performance standards now in existence will be reviewed and updated by EPA based on the best engineering information that is currently available. The main emphasis of this research program will be on providing to industry cost-effective and energy-efficient control alternatives that will meet the standards.

To control nitrogen oxides, research will be conducted to determine combustion modification (CM) methods for reducing NO_x emissions and for improving the performance of industrial furnaces. Prior work on utility boilers has proven that CM methods can effectively control NO_x as well as other emissions. Future research efforts will tailor CM methods to the characteristics of the many types of furnaces, e.g., stoker boilers, steamers, package boilers, cyclone, wall-fired burners and heavy oil burners.

Research will also develop a technical basis for estimating the lowest achievable nitrogen oxides emissions from current and future combustion equipment and fuels. This research will support technology developments and enforcement activities. Emission reduction methods from stationary internal combustion (IC) engines using fuel modification and oil or exhaust gas treatment will also be assessed.

For controlling gases and particles, research will test the electrostatically enhanced fiber filter (ESFF) technology to define cost-effective means of applying baghouses in conjunction with dry-SO_2 systems. SO_x removal with this technology will provide an alternative to costly wet flue-gas desulfurization (FGD) systems. Further research will develop a better fundamental understanding of the operational characteristics of devices, processes and materials for controlling gases and particles.

The shift of electric power utilities to dry scrubbing for low-sulfur coals requires performance tests using varying coal types as a prerequisite to NSPS revisions. Assessments will also explore the feasibility of combining several controls, including coal preparation, for obtaining more effective pollutant removals.

Electrostatic precipitator (ESP) research to define the mechanisms and principal parameters for two-stage ESP operation with low-sulfur coal fly-ash will be completed in 1983. Using comparative assessments, design parameters for two-stage collector stages will be defined. A design report will be produced to assist vendors and users to adopt this lower-cost ESP technology.

Chapter Six
ACIDIC DEPOSITION

ACIDIC DEPOSITION

Outline:

Introduction
Legislative Mandate
Background
Major Research Issues

- **Issue:** What are the relationships between sources and receptors?
- **Issue:** What are the quantitative relationships between acidic deposition loadings and their effects?
- **Issue:** Has acidic deposition been increasing?
- **Issue:** Is liming of acidified lakes cost-effective?

INTRODUCTION

The term "acidic deposition" means the atmospheric deposition of acidic or acid-forming compounds in either their dry or wet form. These compounds exist in the atmosphere as gases or aerosol particles. The gases are sulfur dioxide (SO_2), nitrogen oxides (NO_x) and hydrogen chloride (HCl). The aerosol particles are sulfuric acid, nitric acid (a gas in the troposphere) and certain sulfate and nitrate compounds. While scientists generally agree that these compounds are responsible for deposition of varying degrees of acidity, there remain major uncertainties regarding the causes, extent, consequences and cures for the problem.

The major scientific issues are:

- Has acidic deposition been increasing?
- What source/receptor relationships should be used to determine emission control strategies? Compare deposition from local sources with deposition transported from distant sources? Determine the importance of acid aerosols from natural sources?
- What are the quantitative relationships between acidic deposition loadings and their effects?
- Is liming of acidified lakes a promising mitigative option?

To answer these questions and to provide the scientific and technical data that regulators and legislators need for formulating policy, EPA and other federal agencies are conducting a major research program.

EPA's program is investigating: (1) the relationships between man-made emissions, precursors, and acidic deposition, (2) the processes influenced by the formation and transport of acidic and acidifying substances, (3) the deposition of acidic substances on terrestrial and aquatic systems, and (4) effects of acidic deposition on aquatic environments, drinking water, agriculture, natural terrestrial ecosystems and materials. The program will provide assessments to support policy analyses that determine the cost effectiveness of potential control strategies.

The acidic deposition research program for fiscal year 1983 is allocated $12.5 million, which is part of the $22.3 million budget of the Interagency Task Force on Acid Deposition. EPA's resources are divided among the programmatic categories of the interagency task force as follows: man-made sources, $1.1 million;

atmospheric processes, \$3.9 million; deposition monitoring, \$1.6 million; aquatic impacts, \$1.9 million; terrestrial impacts, \$1.5 million; effects on materials, \$0.4 million; and assessments and policy analysis, \$2.1 million.

LEGISLATIVE MANDATE

EPA's program is a component of, and operates in cooperation with, the National Acid Precipitation Assessment Program (NAPAP), established by Congress in 1980 under the Energy Security Act. Management of the NAPAP research is being handled by the Interagency Task Force on Acid Precipitation, which is jointly chaired by EPA, the Department of Agriculture and the National Oceanic and Atmospheric Administration, and includes research representatives from those agencies and from the Departments of Interior, Health and Human Services, Energy, Commerce, State, the Council on Environmental Quality, the National Aeronautics and Space Administration, the National Science Foundation and the Tennessee Valley Authority. The federal research program has a ten-year legal mandate. It oversees all federally funded acidic deposition research projects. EPA has a coordination role in the task groups for aquatics, control technology, and assessments and policy analysis. EPA also has a major research program to study man-made acidic deposition sources, atmospheric processes, deposition monitoring and terrestrial and materials damage.

BACKGROUND

Acidic deposition has most likely occurred in cities for several centuries. It was first described by Robert Angus Smith in Manchester, England, in 1853. In the United States, acidic precipitation (snow, sleet, rain, hail) has been measured over a large portion of the eastern states for the past 25 years.

The formation of acidic deposition begins when atmospheric SO_2 or NO_x, as either gases or liquid droplets, are oxidized by other airborne chemicals to become sulfate and nitrate aerosols or gaseous nitric acid. While these atmospheric transformations are thought to account for the majority of the acidic compounds, some acidic aerosol particles are emitted into the air directly from power plants, automobiles and other man-made sources.

Once formed, acidic gases and aerosol particles can be removed from the atmosphere by either rain, snow or fog, resulting in acidic precipitation. Such atmospheric removal processes are referred to collectively as "wet deposition." If there is insufficient moisture for precipitation to occur the acidic compounds, including SO_2 and NO_x not oxidized to aerosol particles, can settle or diffuse to the earth and be deposited in a dry form, eventually oxidizing or combining with water (and also oxidizing) to produce sulfuric or nitric acid. This phenomenon is called "dry deposition."

Atmospheric SO_2 and NO_x come from man-made emissions as well as from natural sources. The chemicals which serve as efficient oxidizing agents in the atmosphere primarily are believed to come from photochemical reactions involving volatile organic compounds (VOCs) and NO_x.

Estimates of man-made SO_2 emissions show that 65% of U.S. emissions come from electric utilities and the remainder from various industrial and transportation sources. Estimates of man-made NO_x emissions in the U.S. indicate that more than 40% come from transportation sources, 30% from electric utilities and the remainder from other types of combustion. The primary man-made sources of volatile organic compounds are automobiles, processes that use solvents and facilities for fuel production and distribution.

The natural sources of atmospheric sulfur compounds include marine bioactivity, swamps and volcanos. Estimates of the global sulfur compound emissions from these sources are comparable to those for man-made sources, although man-made processes are responsible for the dominant portion of SO_2 emissions in industrialized areas such as eastern North America.

Estimates of global NO_x emissions from natural sources (microbial activity in soils, burning of forests and agricultural residues, and lightning) are much less certain than are the SO_2 estimates. Current global estimates indicate natural NO_x emissions to be of the same magnitude as emissions from industrial sources. For the United States, however, industrial NO_x emissions are roughly estimated to be ten times greater than natural emissions.

The amount of volatile organic compounds emitted from natural sources is also uncertain. The role of natural emissions in the regional formation of oxidizing agents may or may not be significant.

Whether natural or man-made, all acid-forming compounds and aerosols can be atmospherically transported for distances of a few to many hundreds of kilometers from their point of release to where they return to earth as wet or dry deposition. If deposited in the sea, the acidic aerosols and acid-forming compounds are probably rendered harmless. If deposited on land, however, the compounds may or may not cause an adverse effect, depending upon the nature and sensitivity of the receptor.

The effects of acidification on aquatic life have been demonstrated, to some extent, in the field. However, the extent to which these effects are caused by acidic deposition has not yet been rigorously determined. Quantification of these and other effects on susceptible lakes and streams is currently under investigation. Aquatic effects can manifest themselves as changes in the life forms found in the water. Fishless lakes, for example, can occur when a lake's pH falls below 5 (note: the lower the pH, the greater the acidity; a pH of 7 is neutral). Several reports, scientific studies and surveys conclude that a number of lakes in North America have been affected by acidic deposition. On the whole it appears that a small percentage of lakes or lake acreage may have been significantly affected to date. Some scientists, however, express concern that present deposition levels of acidic and acidifying substances may cause additional aquatic systems to become acidic.

Acidic deposition may also affect forests, crops, soil systems, drinking water, man-made materials and, indirectly, human health. Scientists are now seeking to quantitatively determine if, and to what extent, such effects occur. Because of the complexity of the natural systems involved, however, decisive answers are difficult to come by. For example, after more than a decade of investigations, Scandinavian researchers still find it difficult to demonstrate conclusive cause-and-effect relationships between acidic deposition and forest productivity.

Studies of acidic deposition effects on natural terrestrial ecosystems have shown limited evidence of damage. While acidic deposition may subtly influence the functioning of terrestrial ecosystems, potentially harmful effects may be obscured in the short term by nutrient enhancement from sulfates and nitrates. Recently, however, declines in the productivity of some forest systems have been noted, although the cause for the declines remains unclear. Therefore, a primary concern for research study is the long-term implications of acidic loadings to natural systems.

Few studies have demonstrated that acidic deposition either increases or decreases crop yield.

Nutrient enhancement, again, tends to cloud the issue. One recent report states that a decrease in soybean yield may occur at ambient levels of acidic deposition. However, because plant responses to acidic deposition (in either natural or managed systems) depend on many variables such as soil condition, species sensitivity, life stage, other air pollutants and drought, no major damage to plant productivity has been specifically attributed to acidic deposition. Some researchers theorize that responses to acidic deposition may be occurring but that the responses are being masked by the complexity of the affected ecosystems.

The direct risk to humans from acidic deposition is believed to be very low. The pH of acidic deposition is generally well within the range normally tolerated by human skin and gastrointestinal tracts. Indirect risks to humans which might come from drinking water and food contaminated by acidic deposition are also quite low, except where untreated cistern or well water are used. For example, while acidification of plumbing pipes can cause lead and copper to leach into cisterns, untreated well water and drinking water, most urban and municipal water systems control pH levels to reduce such corrosion. Surveys will indicate whether pH is a problem in smaller systems.

Acidification can also release heavy metals such as mercury and cadmium from lake and stream sediments making them available for uptake by fish. These heavy metals, it is theorized, may accumulate in fish tissues which may, in turn, be consumed by humans. Although such effects could occur, current evidence does not indicate that acidic deposition is a human health problem.

Among the many research projects that are part of the federal acidic deposition research program are several that address the entire range of acidic deposition issues. Two such projects are part of EPA's program. The first involves production of a major report summarizing the state of scientific knowledge with regard to all aspects of acidic deposition. This critical assessment of the acidic deposition phenomenon will be published in 1983. The second project involves completion of an integrated cost-benefit assessment framework for linking emissions models, atmospheric models and effects relationships. This framework, intended for use in policy-related studies, will be available in 1986.

MAJOR RESEARCH ISSUES

Issue: What are the relationships between sources and receptors?

The atmospheric chemistry processes that form acidic deposition are being studied in order to develop source/receptor relationships. Through mathematical modeling and other means, quantification of atmospheric processes will help scientists to understand several key factors. For instance, scientists know that the presence or absence of certain oxidants, other chemicals, moisture and particulates influence the conversion of SO_2 and NO_x to atmospheric acids, but the complex interactions of all these elements have yet to be unravelled. Likewise, ozone and hydrogen peroxide are known to play a significant role in the formation of oxidants, but their actual effect on the conversion has yet to be determined.

Another major requirement for defining source/receptor relationships is the identification and measurement of factors that control atmospheric transport of acid-forming compounds and aerosols. The intricacies of meteorological mechanisms, which are just beginning to be understood, make it difficult to specify the atmospheric paths along which compounds may be transported.

As part of EPA's research effort, large-scale meteorological models are being refined. One current shortcoming is that the models assume that the rate of conversion of sulfur and nitrogen compounds to acidic compounds is proportional to their respective atmospheric concentrations -- in other words, the more SO_2 present in the atmosphere, the more acid sulfate produced. Theory and experimental evidence show that this assumption may be too simplistic to describe actual photochemical conversion rates. Because of this, models are now being improved to include the influences of the mix of oxidants, chemical competition for oxidants, and the presence of aerosols and particulates to act as reaction sites. The refined models will also be designed to more accurately reflect the vertical transport of compounds between various layers of the atmosphere than do current models. Horizontal transport rates, and hence the extent of dispersion, depend in large measure upon vertical exchange rates.

Another problem with using existing models to differentiate between deposition from local and long-range sources is that calculations for sulfur compound deposition are far more developed than are those for nitrates. In some areas, locally produced nitrogen oxides may make an important contribution to acidic deposition.

Finally, long-range transport models only indicate the contribution of emissions from geographic areas; they do not indicate those from individual sources or types of sources. Thus, the models cannot differentiate among emissions from utilities, industries, homes or automobiles. Until refined to do so, their usefulness, especially in formulating and testing control strategies, is limited.

In 1983 EPA, NOAA, DOE and TVA will begin field studies and the development of better atmospheric models to provide more information about long- and short-range acidic deposition transport and the relative importance of wet and dry deposition. An inventory of acid deposition precursor emissions data will be developed to support the modeling research. Model data will also help to determine oxidation reaction pathways and atmospheric oxidant concentrations.

Building upon the results of this research, numerical transport models are expected to demonstrate improved source/receptor associations. The research will include models for examining long-range transport and regional aspects of acidic deposition and a comprehensive field study of source-receptor relationships using atmospheric tracers. These results will be available in 1986 and 1988.

Among the other major planned research products associated with this issue are:

- Produce a completed electric utility simulation model for emissions forecasting for use in 1985.
- Provide a comprehensive emission inventory system by 1985.
- Complete an industrial simulation model for emissions forecasting in 1985.
- Produce a report in 1986 to define the relative importance of deposition from local sources.

Issue: What are the quantitative relationships between acidic deposition loadings and their effects?

By studying the physical, chemical and biological characteristics of lakes, streams and watersheds and the relationships between amounts of acidic deposition in a watershed and the pH levels in an aquatic ecosystem, EPA research will seek to quantify the relationship between acidic deposition loading and ecosystem effects. One of the main problems facing this effort results from dramatic local variations in the buffering capacity of watersheds.

The buffering capacity of a lake and its watershed are the main factors in determining a lake's ability to neutralize acidity. Sensitive aquatic systems have watersheds with little or no neutralizing capability in the soils and bedrock. As a result, such systems have insufficient means to neutralize incoming acids. Areas suspected to be sensitive are generally mountainous, with shallow soils underlain by granitic bedrock. Such areas include portions of New York, the New England states, the Appalachians, the Ozarks, the Rockies, Sierras, and Cascades, the provinces of Ontario, Quebec and Nova Scotia, and mountainous areas in western Canada.

Buffering capacity varies with the nature of underlying rocks, surrounding soils and vegetation in the watershed. Lakes in watersheds with low buffering capacity may become acidified, while lakes in the same region with watersheds having a higher buffering capacity, may not. The Adirondacks, southern Ontario and Nova Scotia are the main regions where some lakes are believed to show the greatest effects from acidity. In addition, areas of the Southeast and Upper Midwest are also sensitive to acidic inputs due to the poor buffering capacity of the soils in these regions.

Many lake features influence susceptibility to acidic deposition. A lake's size and depth, its rate of "flushing" (water flow through) and whether it is fed by surface water or ground water all help to determine how it responds to acidic deposition. Lakes that are poorly buffered and unable to neutralize much acid are particularly susceptible to surface water inflows with low pH's. Surface water with a low pH can be caused by acidic deposition, land use practices, natural "humic" processes or a combination of all three. A dramatic decrease in a lake's pH can occur in the spring when acids accumulated in the melting snow flow into a lake. This episodic phenomenon, known as "spring shock," can deplete fish populations and the lake's pH can decrease quite drastically. Weather patterns also play a role. Local air turbulence and eddys of rain and snow over hills and mountains contribute to the local variability of acidic deposition impacts.

The manner in which land is used in watersheds is also an important factor contributing to potential lake acidification. Logging may be important because it causes a dramatic shift in an ecosystem's nutrient cycling. Around populated lakes, effluents from residences may neutralize some lake acidity.

To determine the extent and magnitude of lake and stream acidification and the associated loss of commercially important fish the EPA, the Departments of Interior, Agriculture and Energy, the Tennessee Valley Authority, industry and several states are cooperating in a major research program. One goal of the program is to develop a national inventory of the impacts of acidic deposition on the quality of surface waters, including drinking water. Another goal, scheduled for completion in 1983, is the preparation of regional and national tabulations and maps showing the distribution of acidified, and acid-sensitive, waters. By comparing historical water quality data with watershed studies, the research will assess the rates of change in water chemistries and thus provide information for evaluating future water conditions. Field surveys will be added in 1984 to inventory the biological impact of acidification on fish.

Correlations among research results will help to reveal the causes, as well as the extent, of altered aquatic systems. A major assessment of atmospheric deposition loading limits for aquatic ecosystems effects will be published in 1985. Reports to assess damages to aquatic ecosystems in physical and economic terms will be published in 1986 and 1988. Another assessment, this one of terrestrial effects in economic terms, is scheduled for 1985 with updates in 1987 and 1989.

Issue: Has acidic deposition been increasing?

Regardless of where acidic deposition has been observed and measured, there is insufficient evidence to state with certainty that the acidity of precipitation is increasing in North America. Historical data are simply too meager. Useful historical data could be gathered from glaciers and ice fields of the Arctic, Greenland, the Antarctic and high mountains. Theoretically, snow and ice core samples taken from the ice masses should contain a record of the trends in the chemistry of acidic deposition. From those records scientists should be able to determine patterns of acidic deposition over hundreds of years. To date, however, the few efforts to detect such patterns have not produced definitive results. One key problem is determining whether the acidity in the samples comes from man-made sources or from natural processes. Preliminary results from studies of glaciers do indicate that SO_4 and metals deposition have increased since the industrial revolution.

Historical records about U.S. air quality are also inadequate for establishing scientifically rigorous trends regarding atmospheric acidity or the concentrations of precursor chemicals. In this case, there is a need to understand natural cycles, or geocycles, to avoid misinterpreting "apparent" short-term trends.

In Scandinavia, where acidic deposition data records are more complete than in North America, analyses suffer similar shortcomings. Strong correlations found between the concentrations of sulfates and nitrates in precipitation and precipitation acidity are not reproducible when sulfur emissions data are collected from arrays of monitoring stations over extended time intervals. The differences in correlation between concentrations and emissions may reflect year-to-year variations in atmospheric transport patterns or the complexity of atmospheric mechanisms.

EPA and other federal agencies are currently gathering data to determine acidification trends. Effects studies include the examination of tree rings, lake sediment cores, acidification damage to tombstones, and an analysis of historical acidity measurements. To gather precipitation data, EPA participates in the National Trends Network (NTN) which will have 150 precipitation chemistry monitoring sites in the U.S. Presently, EPA also supports the National Atmospheric Deposition Program (NADP), a federal, state and private program that operates 110 monitoring sites, most of which will shortly become part of the NTN when the two programs merge. EPA is also cooperating with other agencies in initiating a research program to quantify dry deposition loadings in the U.S.

An assessment of forest effects from acidic precipitation using tree ring analysis is due in 1984. Similar assessment reports of effects on man-made materials and cultural resources will be available in 1985 and 1989.

Among the major planned research products related to this issue are:

- A major evaluation of dry deposition measurement techniques, along with recommendations for monitoring network designs, will be produced in 1983 and updated in 1985.
- An assessment of trends related to acidic deposition will be published in 1985 and updated in 1989.

Issue: Is liming of acidified lakes a promising mitigative option?

One suggested method for protecting and restoring susceptible lakes is to add lime to neutralize the acids. Studies of Swedish lakes and streams demonstrate that adding lime to the water restores fish habitats, enables restocked fish to survive and reproduce, and causes undesirable plant species common to acidic water to disappear. However, the protection of lakes continuing to receive acidic inputs would require periodic reliming, varying from annually to once every five years.

The Fish and Wildlife Service of the Department of Interior is working with EPA to conduct field research on lake liming in North America. Liming strategies to protect against "spring shock" and to trap metals in the watershed before they enter streams are being tested. Additional liming research is being funded by the private sector and by Canada.

These separate research activities will identify where liming is practical and will quantify both beneficial and adverse effects. A report on the economic and biological feasibility of liming as a mitigation measure will be produced in 1984. Final recommendations on the use of liming will be made in 1986.

Among the major research products associated with this issue is the publication of a cost-benefit assessment of acidic deposition mitigation strategies. This assessment will be published in 1987 and updated in 1989.

Chapter Seven
ENERGY

ENERGY

Outline:

Introduction
Legislative Mandate
Background

- Synthetic Fuels
- LIMB/Low-NO_x

Major Research Issues

Issue: What are the key synfuels-related pollutants?

Issue: What are the health and environmental risks of synfuel-related pollutants?

Issue: What are the reliability and effectiveness of alternative synfuel pollutant emissions reduction technologies?

Issue: What is the best approach to monitoring synfuel-related pollutants?

Issue: How do boiler conditions influence key pollutant-related reactions?

Issue: What configurations employing LIMB/Low-NO_x burners show promise of reduced emissions control costs?

INTRODUCTION

In the past few years, adequate energy supplies and a decrease in the growth of overall energy demand have effectively reduced the short-term crisis orientation of America's energy policies. These developments are reflected in EPA's energy research program. The program has been reduced in scale, its efforts have been more clearly focused and the timeline for results has been extended. These changes give EPA an opportunity to help to resolve energy-related environmental problems at a more considered pace.

A number of major projects are planned or under way and the program is still meeting its primary objective -- to provide EPA offices, federal, state and local governments, and industry with the scientific information necessary for producing and using energy resources in an environmentally acceptable manner.

EPA's energy-related research addresses two major subjects: alternate fuels (including synfuels), and limestone injection multistage burner (LIMB)/low NO_x emissions reduction technologies.

The alternate fuels program will evaluate the transport, fate and effects of pollutants associated with the production and use of synthetic fuels, and will investigate alternative emissions-reduction techniques. EPA-initiated research within the synthetic fuels industry takes advantage of EPA's experience in analyzing waste streams, pollutant loadings, health and environmental effects, emissions reduction technology strategies, cost/benefit relationships and regulatory requirements of various energy technologies. Such research efforts now will help to avoid costly future corrections in the emerging synfuels industry by identifying potential health and environmental risks, and by providing information on the cost and effectiveness of pollution control strategies before plants are designed and built. To achieve these benefits, EPA plans to initiate an intensive program to characterize discharge and emissions reduction technology in the first large U.S. commercial plants that will start up in 1983 and 1984. The process for permits to build and operate synfuel facilities will be improved to reduce delays, and the technology to minimize the pollutant emissions will be incorporated at an early stage, not added on at a later time. In some instances, the reduction of pollutant emissions may actually improve overall plant efficiencies.

The LIMB/low NO_x research will provide engineering and design information for promising emission reduction technologies for new and existing industrial and utility boilers. This information may prove invaluable for states involved with the acidic deposition issue and for plants which may be required to further reduce their air pollution emissions. The energy-related research program for fiscal year 1983 is allocated $12.5 million. This total is divided among the major research disciplines as follows: environmental engineering and technology, 77%; health effects, 19%; environmental processes and effects, 4%.

LEGISLATIVE MANDATE

Air and water pollutants and solid wastes result from the production and use of fuels. These pollutants are subject to environmental regulations and enforcement specified in the Clear Air Act, Clean Water Act, Safe Drinking Water Act, Resource Conservation and Recovery Act, Toxic Substances Control Act and the National Environmental Policy Act. EPA research to support regulations and enforcement responsibilities is mandated, directly or indirectly, by these six federal acts.

For the synfuels program, EPA is authorized to provide scientific information for the permit process and preparation of environmental impact statements, for consultation with the Synthetic Fuels Corporation in reviewing new synfuel facilities, for characterization of the potential discharges and review of alternative methodologies which reduce emissions and discharges, for evaluation of the need for the establishment of pollution standards, and as assistance to federal, state, and local governments and industrial organizations. In addition, Section 131(e) of the Energy Security Act of 1980 directs EPA to provide scientific consultation, on environmental monitoring technology and procedures, to synfuel projects supported by the U.S. Synthetic Fuels Corporation.

BACKGROUND

Synthetic Fuels:

- What are the key pollutants that result from the production and use of synfuels?
- What are the health and environmental risks of synfuel-related pollutants and fuels?
- What are the reliability and cost effectiveness of alternative technologies for reducing synfuel-related pollution?

- What is the best approach for monitoring synfuel-related pollutants?

Research and development planning has begun for the task of collecting data on the five large synthetic fuel plants (Great Plains, Cool Water, Eastman, Wood River, Union Oil) expected to start up in 1983-1984. Because there are no full-scale synthetic fuel facilities currently operating in the United States (except for smaller, industrial low-Btu gasifiers), very little data is available at this scale. New pollution reduction technologies have been applied only at bench- or pilot-scale levels. Some emissions reduction technology has been applied at full scale, but adequate data is not available and major problems are known to exist. In most cases, synfuels emissions reduction technology is being designed by engineering extrapolation from other industries.

Given these limitations, the initial research has evaluated foreign facilities, and has incorporated laboratory or pilot-scale research results into the development of models that will provide data on expected operations. Because the environmental control technology for synfuel plants is in an embryonic state, some problems may arise in relation to the effectiveness and reliability of the technology. These problems may need to be corrected on a quick-reaction basis. As demonstration facilities are constructed and more experience is gained with them, the verification of initial results will progress.

EPA has been collecting data from its own research activities and those of other federal organizations, private industry and foreign researchers. These sources have been investigating the occurrence and potential effects of synfuel plant pollution for some time. Research within the Department of Energy (DOE) addresses reproductive, genetic and carcinogenic effects and the environmental cycling of synfuel pollutants in aquatic and terrestrial systems. The National Institute for Occupational Safety and Health (NIOSH) has conducted some research into worker health effects of synthetic fuel plant exposures. Data from synfuel plants in Yugoslavia and South Africa has also been evaluated by EPA. These data consist of a characterization of effluents from a Lurgi gasification plant and a study of morbidity and mortality rates associated with specific plant operations. Ambient monitoring and fugitive emissions data are also available from the Yugoslavian facility. These plants are not necessarily representative of the U.S. plants that will start in 1983-1984; both the technology and the fuel characteristics differ substantially. Nevertheless, because they are the only operating data available, they are being evaluated to assess the potential risks of operations in the United States, to help quantify control levels, and to help EPA to determine whether treatment or removal of potentially dangerous materials is necessary.

EPA has worked closely with the Department of Energy in many areas of synthetic fuels research and development. Over the past several years, EPA has gained access through DOE to most of the synfuel pilot plants, including Solvent Refined Coal (SRC) I and II, Exxon Donor Solvent (EDS) and the H-coal plants. DOE is the operator of these plants and provides detailed analysis of the product materials. EPA has developed and continues to improve upon screening methodology applicable as an indicator of appropriate emissions reduction technology. EPA has also co-sponsored with DOE the evaluation of a pilot Stretford (SO_x removal) unit and emissions testing at the Department of Interior's installation at Fort Snelling, Minnesota. EPA and DOE have also participated jointly in the Industrial Gasifier Commercialization Program. In this program, which involves the use of synthetic fuels gasification to power industrial applications, EPA has focused on short-term source testing, while DOE has concerned itself with long-term health effects.

Another area of cooperation is combustion testing. DOE makes test fuels available to EPA, and tests the fuels for combustability and efficiency (heat content). EPA's job is to check the emissions, compare them to petrofuel emissions and test for the presence of hazardous organics. In addition, there is coordinated research planning between the two agencies on treatability of wastewater from synfuel plants. EPA has also cooperated with the Department of Commerce (DOC) by providing them with test recommendations. EPA is focusing its research and development efforts to learn how existing pollution control devices will act on synfuel plants, and to quantify the synfuel-based emissions by plant configuration and fuel characteristics.

LIMB/low NO_x:

- How do combustion conditions in a boiler combustion zone influence subtle physical and chemical reactions?
- Are there LIMB configurations (fuel preparation, low-NO_x burner, particle collection) which show promise of reduced emissions reduction costs?

EPA's research is producing fundamental and bench-scale information. In cooperation with boiler and/or burner manufacturers, additional EPA research projects will provide prototype-scale information. To carry the research one step farther, in cooperation with foreign efforts (e.g., the Federal Republic of Germany), the EPA program may seek to develop information relating prototype-scale engineering data with full-scale field applications.

MAJOR RESEARCH ISSUES

The major questions or issues to be addressed by the synthetic fuels and LIMB/low NO_x research programs are:

Issue: What are the key synfuels-related pollutants?

Pollutants will be produced at various points in the synthetic fuel production and use cycle. The types of pollutants and their concentrations will vary, depending on the processes used to produce the fuel, plant design and the use of the fuel. To develop adequate pollutant reduction technologies and monitoring plans and to ensure that any hazardous substances are kept below harmful concentrations, synfuel process streams containing potential pollutants need to be identified and loadings determined.

EPA researchers will continue to study pilot-scale and full-scale synfuel plants to identify and characterize plant emissions. This research, plus any data collected on the initial domestic plant start-ups in 1983-1984, will be used to assist permit writers in cases where similar feedstocks and/or conversion technologies are proposed. This will help to ensure the adequacy of environmental permits and impact statements produced for the second wave of synfuel plants (those supported by SFC).

Another major research task is the identification of pollutants from synfuel activities. Of particular concern are those polycyclic organic matter (POM) that are carcinogenic, reduced sulfur species (some of which may be toxic), and hazardous fugitive volatile organic compounds (VOCs). Identification of airborne emissions will receive the most emphasis because of ongoing research and available test facilities. Data collected in field characterization studies will be used as input for risk assessment studies.

Research on synfuels from coal, peat, oil shale, tar sands and heavy oil will target those fuel production processes which are most likely to reach commercial use at an early date. This effort will consist of planning and tracking for the 1983-1984 start-ups, plus some work on the Westinghouse comparative (synfuels-to-petroleum) combustion testing, cooling tower wastewater emissions and hazardous volatile organic compounds.

Pollutants from an oil shale synfuel facility will be studied either at the Union B site in Colorado or at the Chevron site in Salt Lake, beginning in 1984. Research activities will include characterizing air emissions and the constituents of wastewater used to moisten spent shale piles, identifying and measuring leachate runoff, evaluating the physical stability of spent shale piles and evaluating the potential for local vegetation to take up toxic elements caused by shale processing.

Over the next few years, the trend will be, first, to characterize emissions from relatively uncontrolled domestic pilot plants and foreign full-scale facilities, and later, to extend the research to well-controlled domestic full-scale plants. This second phase will indicate how well controls can be expected to reduce the impacts of pollutants of a future synfuels industry.

Major planned research products associated with this issue are:

- A preliminary environmental risk analysis for synfuels and shale oil production will be made available in 1983.
- A report on comparative combustion technology, cooling tower emissions and hazardous VOCs will be produced in 1984.

Issue: What are the health and environmental risks of synfuel-related pollutants?

Regulatory and enforcement decisions rely on accurate analysis of risks to health and environment. EPA integrates exposure and effects assessments of synfuel pollutants into risk analyses which can be used to evaluate potential health and environmental impacts of the pollutants. The assessments consider meteorological, hydrological, demographic and environmental characteristics specific to the location of synfuel facilities.

EPA's research will also produce technology-based risk analyses for coal gasification, direct and indirect liquefaction technologies, and oil shale. The research will also provide risk analyses for other synfuel technologies in support of the permit process and the Synthetic Fuels Corporation. The information from the research can be used to examine such questions as: Will hazards be reduced if the plant is sited elsewhere? What are the cost/benefit considerations for locating the plant at different sites? What levels of environmental control are appropriate for the area in which the facility is to be located? What are the hazards associated with not having additional controls? What reduction of hazard occurs with additional controls?

The research method in risk assessment uses a risk analysis unit (RAU) approach in which chemicals are grouped into classes based upon their occurrence in waste streams and their biological, physical and chemical characteristics. Chemicals identified from the data collected by EPA will be placed in RAUs, each of which will then be analyzed to determine the health and environmental risks of the entire RAU. The research program will determine which RAUs are insignificant and need minimal attention, and which RAUs constitute a potential hazard and therefore must be more intensively studied.

Research will focus on RAUs, upgrading the documentation of the impacts for critical classes of synfuel pollutants, refining the data about exposure pathways within atmospheric, aquatic and terrestrial media; and providing dose/response data for health and environmental effects. Major research areas include:

- Continued development of models for predicting the transport and transformation of synfuel pollutants in the atmosphere, and in aquatic and terrestrial systems.
- Evaluation of the impact of synfuel pollutants on terrestrial and aquatic food chains with emphasis on the uptake of synfuel chemicals and their by-products by food chains leading to humans.
- Documentation of the importance of major organic air and water pollutant RAUs to provide estimates of ground-level concentrations.
- Documentation of human health impacts for synfuel pollutants as determined from occupational and ambient exposures.
- Evaluation of exposure and human effects to develop dose/response functions for carcinogenic and

reproductive risk analysis under ambient environmental conditions and within the workplace.

Major research milestones associated with this issue are:

- Initial health effects risk analyses for indirect and direct liquefaction and shale oil production will be provided in 1983.
- A report on exposure-health relationships in coke oven workers -- a surrogate for coal-based synfuel technologies -- will be made available in 1984. This work re-evaluates some of the earlier studies by employing new data and updating those studies.
- A report on the uptake of synfuel pollutants by vegetation will be produced in 1984.
- An environmental risk analysis update for indirect and direct liquefaction technologies will be produced in 1984.
- A summary report on aquatic exposure/toxicity data, wildlife toxicology and atmospheric transformation rates and products for major Risk Analysis Units will be produced in 1985.

Issue: What are the reliability and effectiveness of synfuel pollutant emissions reduction technologies?

Each synfuel production process has its own pollution output, which may be discharged to air, water or land. Different pollutants require different degrees of control and there are numerous control options to choose from. Before deciding on a set of emissions reduction technologies at a plant, a detailed comparison of control alternatives will help to meet emissions limits at the least cost.

EPA's research program stresses the evaluation of existing synfuel pollutant reduction technologies for performance, reliability and cost trade-offs. A minor effort will investigate a novel technique for difficult, high-cost clean-up problems. Data will continue to be collected from pilot-scale plants. When a commercial-scale plant comes on line, it will serve as the validation mechanism for the earlier data.

Other EPA-sponsored research will test new methods for removal/recovery of sulfur species (COS, H_2S, CS_2) from synfuel gas streams. For example, the Claus/Scott and Stretford processes on high-CO_2 gases, plus key solvent evaluation for acid-gas cleanup, will be investigated. Wastewater treatability studies are focused on post-biological treatment. Emissions reduction technology and characterization data are being used to complete a set of pollution control technical manuals for specific commercial synfuel processes. The data is also being used to provide environmental engineering support to the regions and states on environmental impact statements and permit reviews.

A major planned research product associated with this issue is publication of a major report on sulfur clean-up technology and wastewater treatability in 1984.

Issue: What is the best approach to monitoring synfuel-related pollutants?

Synfuel products and processes may pose greater health and environmental risks than those associated with traditional petroleum and coal combustion facilities. Development of the synfuels industry requires the assurance that the industry poses no unacceptable risks to human health, welfare or the environment. Such assurance depends on factual data that pollution from synfuels facilities are not reaching unacceptable levels. Monitoring will provide this factual data.

The environmental monitoring issue is specifically identified in the Energy Security Act of 1980. All applicants who plan to build synfuel plants with financial assistance from the Synthetic Fuel Corporation (SFC) must provide SFC with an acceptable outline of an environmental monitoring plan. EPA, in conjunction with DOE, will produce the reference information that applicants can use to develop monitoring plans and that the SFC Board of Directors can use in their review of the plans.

Another major function of EPA's synfuels research program is to provide technical assistance to states and EPA regions for monitoring proposed synfuel plants. The assistance will help to ensure that monitoring plans adopted by the states are technically adequate and able to meet requirements set forth in permits.

EPA's synfuels monitoring research will analyze the applicability and cost effectiveness of existing monitoring technologies in terms of their use in tracking the expected synfuel pollutants. The research will identify the species to monitor, and the sites and frequencies of sampling. It will also provide guidance for identifying new species which may not have been present in measurable amounts in pilot-plant emissions.

Results from this research will be published in a single, integrated manual that will describe the monitoring to be carried out and the procedures to use. This manual, to be published in 1983, will represent the state of the art for monitoring with existing technologies. After this manual is published, the research program addressing the synfuels monitoring issue will be reduced until experience with the operational plants indicates that further research is necessary.

Issue: How do boiler conditions influence key pollutant-related physical and chemical reactions?

Complex and subtle physical and chemical reactions take place in the combustion zone of coal-fired boilers. Boiler manufacturers and operators have studied these reactions extensively to make boilers more efficient; the reactions are now being studied to optimize NO_x and SO_x control. For example, lower boiler flame temperature reduces the formation of NO_x emissions. A fuller understanding of the reactions that occur in the combustion zone will enable scientists to understand the cause-and-effect relationships which then can be used to develop engineering design data.

EPA scientists and engineers are addressing a number of questions about the fundamentals of combustion. For example, as the amount of oxygen is varied in the zone, how do NO_x emissions vary? At what portion of the flame front does oxygen injection produce the least amount of NO_x? What compounds are created in different flame zones? Are the compounds destroyed as they pass from primary to secondary to tertiary flame zones? If SO_x and NO_x compounds are destroyed in some portion of the flame can they be kept from re-forming? How does the percentage of sulfur in coal affect the compounds that are formed and the rate of formation? What is the trade-off between SO_x control and NO_x control within the same boiler? What temperature gradients are optimum for SO_x and NO_x control?

Specific studies will determine the mechanisms and rates associated with the volatilization of sulfur species from the coal particle matrix. The studies will also identify the role of fuel-bound nitrogen and its evolution from the coal particle matrix in the formation of NO_x. (Much of the NO_x from combustion processes is a result of fuel-bound nitrogen.) A more thorough determination of the role of the fuel nitrogen in NO_x production is expected by early 1984. The rates and mechanisms associated with volatilization of sulfur species from coal will be determined by 1985.

Once the fundamental reactions indicated by laboratory experimentation are duplicated at prototype scale, the results of the experiments will be used to develop engineering designs. Results from this research will support engineering and design evaluations being done by industry and by EPA.

A major planned research product associated with this issue is a complete performance optimization of industrial boiler low-NO_x burner evaluation in 1983.

Issue: What configurations employing LIMB/low-NOx burners promise reduced emissions control costs?

Limestone injection multi-stage burner (LIMB) technology is an evolving concept for controlling SO_x emissions from boilers. Limestone injected at appropriate places in a boiler combustion zone can chemically capture sulfur compounds, keeping them from being emitted as air pollution. When used in tandem with low-NO_x burners or staged combustion to control NO_x emissions, a LIMB/low NO_x system is a potentially attractive alternative to current wet scrubbers, now in widespread use. The LIMB technology could cut construction costs by as much as 75% as compared with wet scrubbing technology. In addition, LIMB systems produce a dry waste which may be more easily disposed of than wet scrubber sludge. LIMB technology is also appropriate for retrofit to some existing boilers. While LIMB is not expected to be as effective as the wet process in removing SO_x, it could prove to be an invaluable part of an overall system for SO_x/NO_x control. Ultimately, the benefits from a LIMB system will be a dry, less expensive, efficient SO_x/NO_x integrated pollutant removal system applied to utility or industrial boilers.

The key to achieving a commercially acceptable LIMB system is to have one (or more) host boiler operators install and operate such a system under realistic conditions. But such a host may hesitate to make the capital investment in LIMB until there is convincing engineering data to suggest that the investment is sound. Developing that engineering data is the goal of EPA's LIMB research program. It is expected that such data will be available by 1986.

The LIMB research program is proceeding along a number of paths. Fundamental chemical reactions described earlier will be used as a basis to design pilot- and bench-scale LIMB systems for pulverized coal wall-fired and tangentially-fired boilers. Concurrently, scale-up engineering parameters for utility-scale boilers will be developed and cost-effectiveness data evaluated. The objective is to produce the scientific data and engineering parameters that will enable commercial boiler manufacturers to design, build and eventually to produce LIMB systems with private capital. Another research effort involves a systems evaluation of how LIMB can be integrated with other control technologies such as coal cleaning, dry scrubbers, and particulate controls to achieve necessary emissions reductions at the lowest overall cost.

Once the research provides the necessary fundamental information so that commercial LIMB adaptation, scale-ups, and design can take place, the next phase of research is to take performance data from a host operator. Integral to this effort is continuing information exchange and cooperation between EPA and manufacturers and utilities interested in the progress and potential of LIMB/low-NO_x emissions reduction technology.

A major planned research product associated with this issue is the production of a system analysis study of the LIMB process to be available in 1983.

Chapter Eight
EXPLORATORY RESEARCH

EXPLORATORY RESEARCH

Outline:

Introduction
Legislative Mandate
Background
Major Research Issues

- **Issue:** What are the best indicators of an environmental impact?
- **Issue:** What factors control biodegradability?
- **Issue:** What are the most accurate measurement processes for airborne pollutants?
- **Issue:** How do pollutants interact with soils?
- **Issue:** What happens to pollutants at the water-to-air interface?
- **Issue:** Can water treatment be made more efficient through a better understanding of unit processes?

INTRODUCTION

Many of today's environmental problems might have been avoided if in the past there had been a clearer scientific understanding of the physical, chemical and biological relationships among the environment, pollution and man. EPA is focusing much of its research on solving the problems, mitigating the hazards of immediate concern and providing a sound basis for regulations as described in the preceding chapters of this **Research Outlook.** Within that research framework, there is limited room for seeking entirely new knowledge and fundamental scientific information. It is, however, just such information that will yield major advances in controlling today's environmental problems, and provide the means for mitigating future problems. EPA's exploratory research program is the vehicle by which EPA broadens and deepens its base of scientific knowledge.

BACKGROUND

The primary goal of the exploratory research program is to develop new knowledge and principles for defining and predicting the relationships between physical and chemical factors and biological systems. A secondary goal is to identify emerging problems or ways to handle current problems more effectively. The mechanisms used to pursue these goals are research grants. **Research grants** are based on competitive proposals from scientists qualified to investigate specific facets of the environment.

University research centers operate under cooperative agreements with EPA to conduct multimedia/interdisciplinary research focused on specific environmental problems. Each center extends the capabilities of EPA laboratories in specific research areas -- filling research gaps, providing broad-based scientific advice and serving as a source of professionals with an expertise which is valuable to the agency. The current centers and their inauguration dates are:

1979:
Epidemiology--University of Pittsburgh
Advanced Environmental Control Technology--University of Illinois at Urbana
Ground Water--Consortium of University of Oklahoma, Oklahoma State University, Rice University

1980:
Industrial Waste Elimination--Consortium of Illinois Institute of Technology, University of Notre Dame
Intermedia Transport--University of California, Los Angeles
Ecosystems--Cornell University
Marine Sciences--University of Rhode Island
1981:
Hazardous Waste--Louisiana State University

LEGISLATIVE MANDATE

In all proposed authorizations for EPA research and development funds for each fiscal year since fiscal year 1978, Congress has designated a portion of these funds to support what has been variously termed long-term, anticipatory, or basic research and development. Of these bills, four have been enacted: 1978--P.L. 95-155, 1979--P.L. 95-477, 1980--P.L. 96-229, and 1981--P.L. 96-569.

MAJOR RESEARCH ISSUES

The items that follow by no means cover the vast range of topics of interest to EPA's exploratory research program. They are, rather, topics that have been described in the 1983 solicitation for research.

Issue: What characteristics best indicate an environmental impact?

Often descriptors of an environmental impact on an ecosystem only indirectly relate to the vitality of the affected system. Most impact descriptors now in use are physical parameters and concentrations of substances known to affect the environment to some degree. That ecosystems do respond to certain mixes and/or levels of these characteristics is known, but research is needed to determine how systems respond to perturbations and to describe system stability and resilience. In short, what are the characteristics of an ecosystem response?

EPA's exploratory research will survey the data that have been produced to describe environmental stress factors. Ecosystem mixes for healthy environments will be identified and compared with ecosystems that have undergone species diversity changes due to pollution. The comparison will help to identify system variances and the spectrum of responses.

Some significant problems are expected to be encountered in this research. For example, some ecosystem processes operate over long periods and may not reveal responses for some time; a method is needed to identify those responses. Additionally, ecosystems vary based on location, which makes similar pollution inputs significant in some areas but of small concern in others; techniques are needed to differentiate responses by region and other sample parameters.

Once the nature of ecosystem stress is described in detail, investigators may proceed to determine damage on the sub-cellular, physiological and behavioral levels. This, in turn, could improve the capacity for identifying sub-lethal stresses and cause-and-effect relationships. Such a capability could be used to detect problems before individual deaths, population reductions or species extinction.

The long-term objectives of the research are to determine which pollutants can or cannot be handled by defined biological systems, what level of control of pollutants is required to minimize damage and how best to achieve control. A current thrust in the EPA research grants program focuses on methods to determine impacts on organisms comprising the environmental biota in specific locales and to integrate these techniques into a holistic predictive methodology.

Issue: What are the fundamental factors that control the biodegradability of substances?

Ecosystems have the natural ability to recover from exposure to many types and concentrations of pollutants. One of the major mechanisms through which ecosystems neutralize toxic substances is microbial degradation. Although much is known about biodegradation, the basic factors are not fully understood. Moreover, whether pollutants are biologically degraded or whether the intermediate by-products of a pollutant's biodegradation are innocuous could be crucial information for a scientifically correct pollution control decision.

EPA's exploratory research program seeks to develop an understanding of fundamental scientific factors (such as the identity and characteristics of the dominant degrading organisms, the factors influencing the rate of biodegradation and their specific modes of action) involved in biodegradation. The objective of this research is to relate a chemical's characteristics with an organism's degradation capabilities to determine whether specific chemical inputs to an ecosystem containing the organisms will cause damage.

Information resulting from this research will also help improve waste and wastewater treatment, protect water quality and drinking water resources, assist industry to assure that process waste streams minimize problems, and develop regulatory monitoring protocols and test procedures for determining water quality integrity.

Current research includes studies to upgrade anaerobic treatment of industrial and municipal wastewater, to increase process reliability and to realize the energy potential of the methane gas that is generated.

Issue: What measurement processes can more accurately detect fine particles and airborne pollutants?

Scientists need precise data to learn more about the nature and effects of pollutants found in the air. This is especially true for new or exotic air pollutants often found in low, but nonetheless significant, concentrations, and for carbonaceous particles whose importance as agents for promoting chemical reactions and whose potential role as agents for emission control have recently become apparent. EPA's research will produce fundamental chemical and physical knowledge to assist the development of precise instruments to measure low concentrations. In-situ methods may solve the artifact problems. Promising technologies for detecting low concentrations are active remote sensing, such as infrared and laser optical devices, and techniques to analyze wave-front interference patterns to detect compounds. The research will be useful for developing a better understanding of atmospheric chemistry and a more accurate description of the kinetics involved. Ultimately, the research will make air pollution transformation models more scientifically rigorous and, therefore, more useful to EPA.

Issue: How do pollutants travel through, and react with, soils?

To determine how pollutants affect underground sources of water, it is necessary to understand the mechanisms of movement through, and the interaction of pollutants with, the subsurface environment. This subsurface environment plays a dominant role in the transport and fate of contaminants. The aim of EPA's exploratory research in this area is to develop information sufficient to predict ground-water contamination from both existing and future polluting sources. EPA's research in this area is coordinated with the U.S. Geological Survey (USGS). USGS research is directed primarily toward determining the locations, quality and amounts of ground water, including assessing the impacts of contamination on water quality and quantity. EPA research is directed toward understanding the processes that influence contaminant behavior in the subsurface with the goal of predicting the impact of contamination on underground water sources. Current research is characterizing subsurface parameters that influence the ground-water contamination processes, processes that control the mobility and transformation of pollutants, including microbial activity. New techniques to detect and trace subsurface pollution plumes are needed to assure that data collected are of high quality. The sorption characteristics of various classes of organics of concern in ground-water contamination are being mathematically described for inclusion in ground-water models.

Issue: What are the fundamental dynamics of the water-to-air interface that relate to pollutants?

Pollution moves between the three environmental media -- air, water and land. The rates and nature of that movement are controlled by complex, and as yet unclear, chemical, physical and biochemical processes. But environmental protection regulations and the scientific data to support them tend to concentrate on a single phase of the media, which can result in overlooking the contributions of other phases. EPA's exploratory research into the water-to-air interface centers on investigating the basic scientific aspects of intermedia transport and transformation. The research focuses on physical and chemical phenomena, such as solubility and diffusivity, which are known to influence transfer at the interface, and on the roles of suspended sediment and turbulence in the transfer. The resulting information will be used in models to predict concentrations of toxic pollutants in air and water and their variation with other atmospheric and aquatic factors.

Issue: How can water treatment methods be improved through a better understanding of unit processes?

Current water treatment techniques and water pollution control methods use specific physical/chemical/biological reactions, known as unit processes, as their primary means of operation. However, many fundamental mechanisms that influence the performance of unit processes are not well understood. This lack of knowledge has prevented engineers from designing the most cost-effective control systems. To help fill this information gap, exploratory research in water treatment will focus on determining the role of bioflocculation and biofilm in wastewater treatment processes and receiving waters, identifying and measuring the influence of particulates on process effectiveness, determining the reaction kinetics, products and reaction mechanisms of oxidants and other alternative disinfectants, describing dislodging mechanisms during filter backwashing and understanding the bioactivity of activated sludges. One of the EPA exploratory research projects in this area is currently investigating a novel approach to water treatment to create polymerization of compounds so that they become insoluble and settle out more rapidly and at lower temperatures. This process would be useful to industries in cold climates that have to store wastes in large holding tanks during the winter until warmer weather enables the use of biological treatment processes. Other research is looking at ways to reduce the volume of sludge and put it in a more treatable form by de-watering it with new moisture-removal methodologies. The research is balanced between gaining a basic understanding of the unit processes and applying that understanding to specific current and expected water pollution control situations. The results of the program should produce information upon which to base future designs of cost-effective water treatment control technology.

APPENDIX A:

Resource Options

APPENDIX A

RESOURCE OPTIONS

The law requiring the submission of this research strategy document to Congress is Section 5 of Public Law 94-475. The same law also requires that a five-year projection be provided indicating the potential research response to different resource levels.

The following section on resource options includes, as required by the law, descriptions of conditions for high, moderate and no growth. The growth rates associated with these options are zero for no growth, three percent for moderate growth and six percent for high growth. No additional resources are required or expected as a result of this submission. Rather, these growth scenarios are intended, as required by the law, to indicate potential program increases in EPA's research and development.

HAZARDOUS WASTE

1983 CURRENT ESTIMATE $33.0 MILLION*

GROWTH	PROJECTIONS			
	1984	**1985**	**1986**	**1987**
None	27.4	27.4	27.4	27.4
Moderate	27.4	28.2	29.1	29.9
High	27.4	29.0	30.8	32.6

Figures are in millions of dollars

No Growth: The program will proceed as described in this **Research Outlook.**

Moderate Growth: Additional efforts will seek to discover the key factors leading to the failure of soil, clay or synthetic liners for hazardous waste land disposal sites.

High Growth: Techniques to detect and monitor subsurface movement of hazardous waste leachate will be further investigated. Emphasis will be on identifying key early indicators of leachate migration problems.

*The 1983 number includes $2.4 million which was used for exploratory research grants and centers. These funds will be included directly in the exploratory research budget in 1984 and, therefore, are not included in these projections.

WATER QUALITY

1983 CURRENT ESTIMATE $30.6 MILLION*

GROWTH	PROJECTIONS			
	1984	**1985**	**1986**	**1987**
None	19.2	19.2	19.2	19.2
Moderate	19.2	19.8	20.4	21.0
High	19.2	20.4	21.6	22.9

Figures are in millions of dollars

No Growth: The program will proceed as described in this **Research Outlook.**

Moderate Growth: Efforts to develop flexible protocols for determining site-specific water quality will be accelerated as will efforts to transfer such capabilities to state and local environmental officials.

High Growth: Efforts will be accelerated to develop regimens for characterizing the ecosystems of potential ocean outfalls and dumping sites. Investigations of early indicators of potentially negative ecosystem responses will also be accelerated. These activities are in addition to those listed above under moderate growth.

*The 1983 number includes $1.1 million which was used for exploratory research grants and centers. These funds will be incorporated in the exploratory research budget in 1984 and, therefore, are not included in these projections.

DRINKING WATER

1983 CURRENT ESTIMATE $23.3 MILLION*

GROWTH	PROJECTIONS			
	1984	**1985**	**1986**	**1987**
None	20.9	20.9	20.9	20.9
Moderate	20.9	21.5	22.2	22.8
High	20.9	22.2	23.5	24.9

Figures are in millions of dollars

No Growth: The program will proceed as described in this **Research Outlook.**

Moderate Growth: Additional efforts will be initiated to determine with greater precision the potential health effects of those substances that are found in drinking water treated via various disinfection processes. Focus will be on those contaminants that are non-volatile and, therefore, have yet to be investigated in any great detail.

High Growth: The additional efforts cited under the moderate growth option above will be augmented and accelerated.

*The 1983 number includes $1.9 million which was used for exploratory research grants and centers. These resources will be incorporated in the exploratory research budget in 1984 and, therefore, are not included in these projections.

TOXIC SUBSTANCES AND PESTICIDES

1983 CURRENT ESTIMATE $33.7 MILLION*

GROWTH	**PROJECTIONS**			
	1984	**1985**	**1986**	**1987**
None	29.8	29.8	29.8	29.8
Moderate	29.8	30.6	31.6	32.6
High	29.8	31.6	33.5	35.5

Figures are in millions of dollars

No Growth: The program will proceed as described in this **Research Outlook.**

Moderate Growth: Investigations into the relationships between a chemical's structure and its chemical, physical and biological properties will be accelerated.

High Growth: Additional efforts will be made to link health and ecological effects with various models that describe the steps in the life cycle of a substance from its production and release to its ultimate destination. Such efforts are in addition to those mentioned under moderate growth above.

*The 1983 number includes $1.5 million which was used for exploratory research grants and centers. These resources will be incorporated in the exploratory research budget in 1984 and, therefore, are not included in these projections.

1983 CURRENT ESTIMATE $59.4 MILLION*

GROWTH	PROJECTIONS			
	1984	**1985**	**1986**	**1987**
None	51.2	51.2	51.2	51.2
Moderate	51.2	52.7	54.3	55.9
High	51.2	54.3	57.5	61.0

Figures are in millions of dollars

No Growth: The program will proceed as described in this **Research Outlook.**

Moderate Growth: Additional work will improve the technology and techniques available for measuring and monitoring hazardous air pollutants.

High Growth: An increased effort will identify more clearly the causes and mechanisms of human responses to air pollutant exposures. This effort will be in addition to that cited under moderate growth above.

*The 1983 number includes $4.7 million which was used for exploratory research grants and centers. These resources will be incorporated in the exploratory research budget in 1984 and, therefore, are not included in these projections.

1983 CURRENT ESTIMATE $12.5 MILLION

GROWTH	**PROJECTIONS**			
	1984	**1985**	**1986**	**1987**
None	14.0	14.0	14.0	14.0
Moderate	14.0	14.4	14.9	15.3
High	14.0	14.8	15.7	16.7

Figures are in millions of dollars

No Growth: The program will proceed as described in this **Research Outlook.**

Moderate Growth: In the source-receptor relationship area, additional efforts will be made to improve methods for identifying the source of a particle by its "fingerprints." Work with tracers will be accelerated.

High Growth: Efforts to delineate between actual acidic deposition trends and other cyclic meteorologic influences will be advanced and the efforts described under moderate growth above will be accelerated.

1983 CURRENT ESTIMATE $12.5 MILLION*

GROWTH	**PROJECTIONS**			
	1984	**1985**	**1986**	**1987**
None	9.5	9.5	9.5	9.5
Moderate	9.5	9.8	10.1	10.4
High	9.5	10.1	10.7	11.3

Figures are in millions of dollars

No Growth: The program will proceed as described in this **Research Outlook.**

Moderate Growth: Efforts to characterize reaction conditions in limestone-injected multistage burner configurations will be accelerated. The information produced will serve to guide the development of more refined (more effective) emissions reduction configurations.

High Growth: The efforts described under moderate growth above will be augmented and accelerated.

*The 1983 number includes $1.4 million which was used for exploratory research grants and centers. These funds will be incorporated in the exploratory research budget in 1984 and, therefore, are not included in these projections.

EXPLORATORY RESEARCH

1983 CURRENT ESTIMATE $17.5 MILLION*

GROWTH	PROJECTIONS			
	1984	**1985**	**1986**	**1987**
None	15.5	15.5	15.5	15.5
Moderate	15.5	16.0	16.4	16.9
High	15.4	16.4	17.4	18.5

Figures are in millions of dollars

No Growth: The program will proceed as described in this **Research Outlook.**

Moderate Growth: The research grants program will be expanded to support additional high-priority, high-quality proposals.

High Growth: The research grants program will be expanded further and high-priority work being undertaken at the university research centers will be augmented.

*Of this figure, a large portion ($13.0 million) is drawn from the other research programs mentioned in this report. The resource figures given for the other programs also include these resources.

APPENDIX B:

Technical Reviewers

APPENDIX B

Technical Reviewers

The entire Research Outlook 1983 was reviewed by the following Science Advisory (SAB) Members:

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