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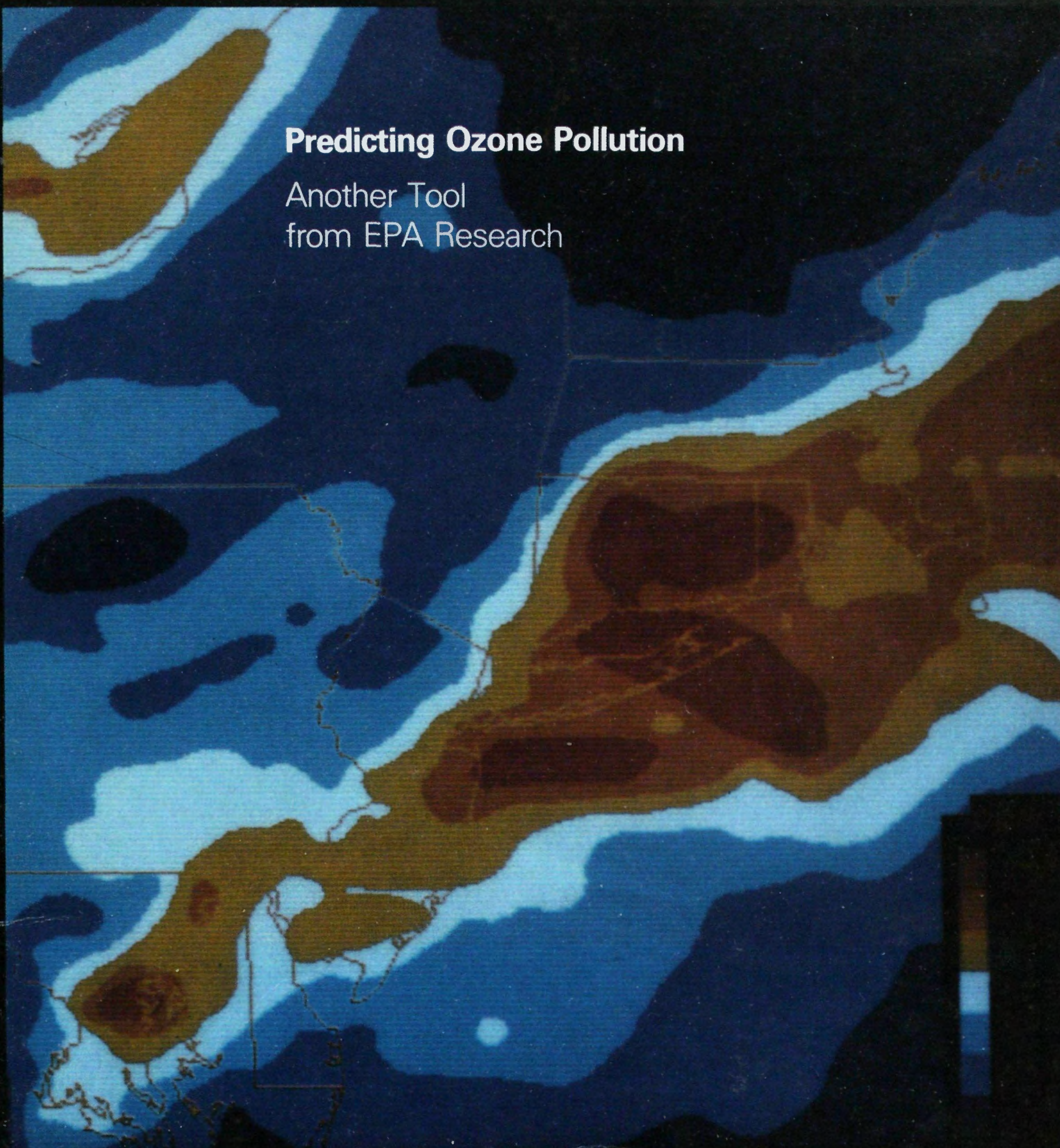


Predicting Ozone Pollution

Another Tool
from EPA Research

Research at EPA

Ice minus...Mesocosms... Microbes.... These aren't subjects for science fiction at EPA. They're the concerns of the Agency's research program as it provides know-how to help implement EPA's regulatory efforts. This issue of *EPA Journal* is about R & D at EPA.

The issue also includes a special feature explaining the goals for the Agency as expressed by Lee M. Thomas, the Administrator.

The R & D portion of this *Journal* leads off with an interview with Vaun Newill, EPA's Assistant Administrator for Research and Development. Dr. Newill's remarks range from acid rain to the study of climate change.

Then eight articles report on various EPA research efforts. The topics fit into four categories: risk assessment, ecological risk, human exposure to risk, and risk reduction. These articles illustrate the emphasis EPA research places on determining the risks from environmental problems and developing methods to help reduce those risks. Next, three features report on technical assistance and international aid flowing from research at EPA.

Under the category of risk assessment, one article explains efforts to reduce the element of uncertainty in determining risks and another reports on studies of the effects of ozone pollution on human health.

Articles about research on ecological risks concern the laboratory creation of aquatic environments to help understand marine pollution, the scrutiny that a recent development in biotechnology has received, and the techniques EPA scientists are using to assess the vulnerability of lakes and streams across the country to acid rain.

Features regarding human exposure to environmental risks include a report on surprising results from studies of people's exposure to pollution inside their homes, and an article on how EPA is using science to project levels of ozone pollution in the U.S.

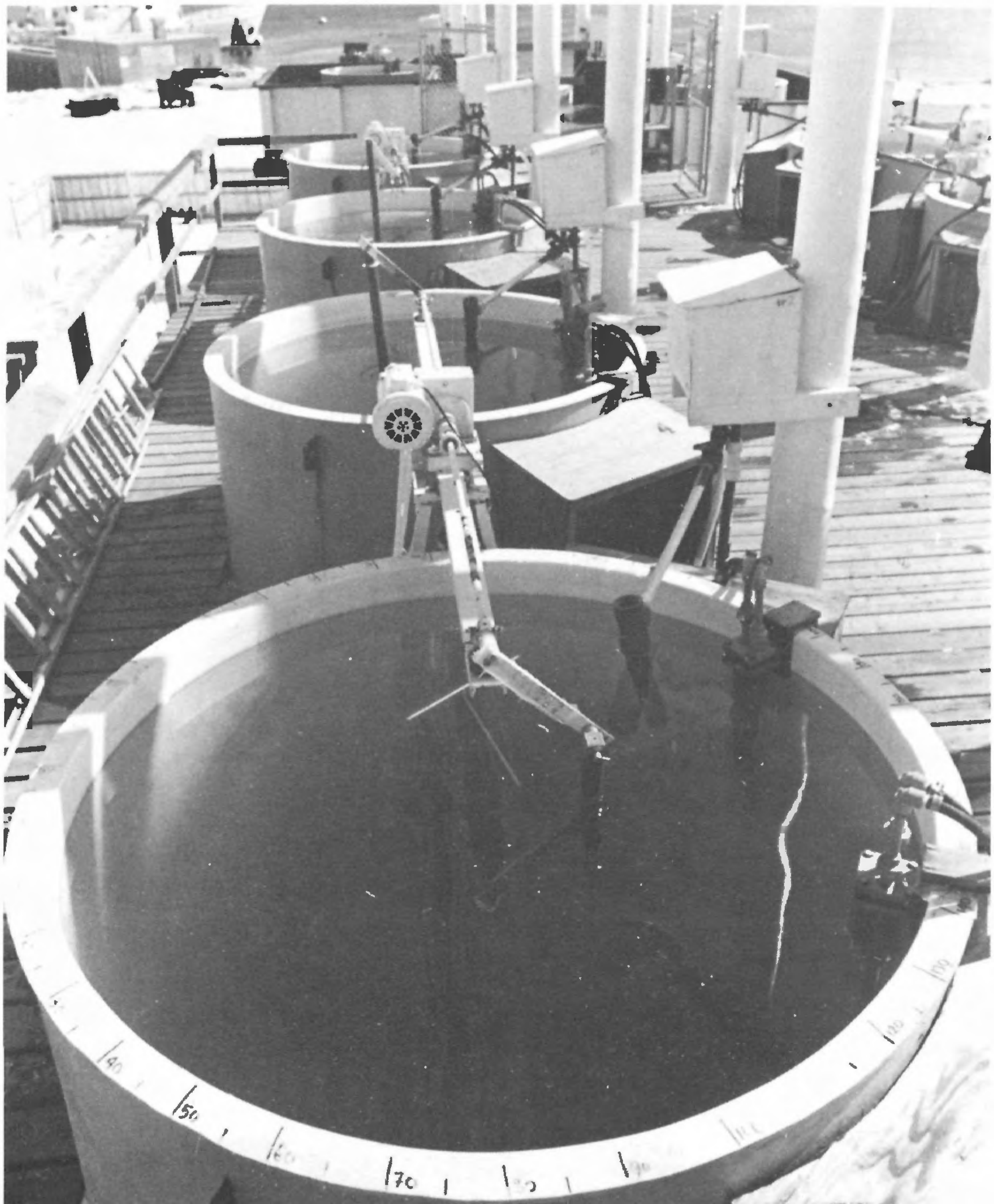
Research to reduce risks is illustrated by an article on the prospect of using microbes to clean up polluted ground water.

Payoffs of EPA research as technical assistance are shown by a report on how EPA is involved in measures to ensure the safety of people living in the vicinity of the Las Vegas, Nevada, nuclear test site. Another article explains how EPA research has helped in the detection of *Giardia lamblia* cysts in water. These cysts are often the prime suspects in outbreaks of gastrointestinal disease.

The final article in the research portion of this issue reports on how EPA know-how is helping to control environmental threats in other countries.

Other articles in the magazine include a report on the Agency's recent proposed regulations to deal with the problem of pollution from underground storage tanks. And two specialists from EPA's Environmental Response Team describe their trip to Cameroon in Africa to help figure out how the Lake Nyos disaster last August killed 1,700 people in a matter of hours.

This issue of *EPA Journal* concludes with two regular features—Update and Appointments. □



Tanks operated as artificial ecosystems at EPA's Marine Ecosystem Research Laboratory at the University of Rhode Island, Kingston.

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EPA is charged by Congress to protect the nation's land, air, and water systems. Under a mandate of national environmental laws, the agency strives to formulate and implement actions which lead to a compatible balance between human activities and the ability of natural systems to support and nurture life.

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Cover picture:
Computer-generated photograph based on ROM projections of ozone concentrations in the northeastern United States. ROM is the Regional Oxidant Model developed by EPA's Atmospheric Sciences Research Laboratory in Research Triangle Park, NC. The model simulates concentrations of 28 chemical substances in the air, depending on such factors as sources and control actions. Pictured is the projected maximum hourly ozone concentration over a 15-day period in July 1980. The colors show the highest hourly ozone concentration in that period. The present primary limit for ozone is 0.12 ppm (parts per million) not to be exceeded more than once a year. Scientists at the laboratory are now adapting the model so that it can be used to predict changes in ozone concentrations that would occur based on various control strategies. See story on page 17.

Providing Environmental Know-How

An Interview with Dr. Vaun Newill

Steve Delaney

Vaun Newill

How does research fit into a regulatory agency like EPA? What are the Agency's scientists learning about current environmental problems? For answers to these and other questions about research at the Agency, EPA Journal interviewed Dr. Vaun Newill, the Agency's Assistant Administrator for Research and Development. The text of the interview follows.

Q **Dr. Newill, you served at EPA back in the early 1970s, and before that, you were in the air program at HEW. Are things different now?**

A Most definitely, but I believe most of the changes are very positive. The most obvious change is that the Agency is much more complex, in terms of process as well as the scope of environmental issues, than when I was here before. We have many more legislative mandates. There has been a definite maturation of the system, so that in some ways, it's more difficult to get work done, but you also get a better responsive product.

Q **Before you came back to EPA, you held a research position with Exxon. Did you bring anything from that experience with industrial research programs that will help in heading up research at EPA?**

A Well, I certainly learned that, in many ways, it's easier to put together a research program at Exxon than it is at EPA. Private industry has its bureaucracy, too, of course, and there are many different groups bringing pressure on you in terms of your program. But it's not the wide variety of groups that you have pressuring you here at the Environmental Protection Agency, not the complexity. However, I think some procedures or approaches used in private industry can be extremely useful, and I have tried to bring some of those to the Office of Research and Development, such as greater emphasis on stewardship and accountability.

Q **Are there major differences in research procedures between industry and government?**

A Not really, because protocols are similar across the scientific community. There are some differences, but these are not related to science. For example, the motivation for conducting research might be different. Industry's focus is generally directed to data development with regard to a product or process and not to developing the basic underpinnings for environmental science. EPA, on the other hand, has to respond to much broader questions, and that requires a much broader based, multi-discipline research program aimed at policy and regulation development.

But I think that the investigators in each place do good experimental design and carry out the work to the best of their abilities.

Q **What is the relationship between basic science and the kind of research conducted by EPA?**

A Well, of course, EPA's research is often driven by the needs of the regulatory programs. But given that constraint, let me emphasize that the difference between basic and applied science is frequently just one of degree. If you were to draw a line, one end being basic research and the other being applied research, clearly much of EPA's work would be toward the applied end. The problem is one of definition; where one ends and the other begins is somewhat arbitrary.

EPA is a client of the basic research community. Often, our scientists take the results of basic or fundamental research, evaluate these findings and then interpret them to help the Agency understand the range of uncertainty associated with our asessments.

Q **How does the Office of Research and Development support regulatory decisions? Can you give examples of cases where your research played a direct role?**

A There's an enormous range of areas in which our research projects had a major influence, so it's hard to know where to begin. Just offhand, I can cite decisions on the PM10 particulate standard, the ozone standard, and diesel emissions that were influenced by our research. Implementation will be based on research we've conducted on monitoring and modeling. We've also played a part by showing the availability or applicability of various control technologies; for example, we've been involved in the development of baghouses, electrostatic precipitators, and fabric filters for air emissions. We also developed the mobile incinerator, which has had an enormous effect on EPA's dioxin program and is being used for the cleanup of soil.

Other contributions include water-quality criteria and methods for nutrient removal and upgrading waste and water treatment plants. We also developed biological test methods which are used in making decisions on the use of new and old chemicals, as well as registration of pesticides. Our work in developing GC-MS analytical techniques for quantifying organics in water and other media set the standards for modern-day analytical laboratories.

In fact, it's hard to come up with an area in which EPA's research has not had a major effect on a regulatory decision.

Q **What about research that is not specifically tied to a regulation? Can EPA research be designed to anticipate environmental problems, rather than react to them?**

A Well, we would like for EPA research to be able to look ahead; we'd like to build a long-term program. But because of the pressure to be responsive to the regulatory agenda, we focus more on short-term research and providing technical assistance than we do on long-term research efforts.

We have not really had a long-range ecological research program, although we have had some ecological research underway for a long time. I want to leave behind a strong and viable plan to enhance the ecological research program at EPA, to take a leadership role in the federal community. I realize that we can't do it all, but we must achieve a balance between ecological and human health risk-related research.

We really do recognize the need for anticipating emerging environmental problems. In large measure, this is why we are collaborating with the Science Advisory Board, to work cooperatively to formulate a long-term research plan addressing risk assessment (health and ecological), exposure assessment, and risk reduction. This should help us focus on research which can lead to the greatest reductions in uncertainty in the risk assessment process. It should also produce a coherent plan which can lead to integration of longer-term research into the overall research program here at EPA.

Q **Can you go out on a limb and predict the long-range problems or emerging environmental issues of the next 15 years?**

A My training as a scientist doesn't give me particular talent with a crystal ball, but there are a few areas that I'd predict are of significant long-term importance. One area is the family of problems having to do with the relationship between Earth and its atmosphere. That includes problems of global climate and stratospheric ozone depletion, and their related health, environmental, and socioeconomic effects.

The scientific community is also devoting considerable attention to ecological issues such as maintaining species diversity and ecological processes. These, of course, have major implications for programs involving everything from endangered species to wetlands, coastal processes to forest and crop health.

Q **You mention global climate and ozone depletion. Do you think we really understand problems like these, understand enough to act on them?**

A What we need to know to *understand* the science of these problems is a great deal; what we need to know to *regulate* is probably not nearly so much. For example, we know that chlorinated fluorocarbons (CFCs) cause depletion of the ozone layer, but not necessarily how they do this. But we've taken action against them. EPA is working to achieve a worldwide reduction in CFC use, possibly even a ban on them. Just the knowledge that CFCs interfere with the ozone layer has been enough for EPA to start taking regulatory action.

In other areas, such as global warming or the greenhouse effect, I think we understand what the greenhouse effect is; we know that it's going to cause a warming trend which will affect the ecology of the planet. But it's going to be more difficult to deal with because as long as we use fossil fuels, as long as we have carbon dioxide emissions and some of the other trace gases that contribute to this effect, it's harder to know what to do. The problem and the solution are long term; therefore, there is urgency in moving forward expeditiously with a research program to develop better understanding and more knowledge for future policy and regulatory action.

Q **Is biotechnology another area where EPA should be looking ahead for long-term consequences?**

A Biotechnology is certainly one of the new technologies that we expect to be widely used in industry. Certainly we need to know if releases (accidental or planned) would cause undesirable effects, on the environment and the population and, if so, how to protect both. We are also looking at the other side of biotechnology, as a tool to clean up wastes. I think this technology has great promise. We're trying to develop the kind of information and the kind of expertise that would help us understand this technology enough to develop appropriate safeguards.

But remember that we are already using naturally occurring microbes to accelerate the biological degradation of certain wastes. Once we have perfected the techniques, we'll also be using engineered organisms to carry out that process.

Q **EPA recently came out with a report comparing risks from various environmental problems the Agency is addressing, including biotechnology. How useful is risk assessment in driving EPA's priorities?**

A Risk assessment—another term is comparative risk—is certainly a tool that's available to us. We take risk into consideration when planning our budget. But I emphasize that it's only one of the tools that we use. Our program priorities are also driven by forces such as legislative mandates. All of these go into the planning, the priorities of the Agency. When you have limited resources, it is useful to use knowledge of risks to attack those that are most likely to be causing the greatest damage. One of the biggest problems facing us is that we do not have sufficient knowledge of how to count the risks associated with non-cancer endpoints or ecological risks. Both areas are ripe for some intensive research.

Continued to next page

Q Your area of expertise is human health. Has government regulation been proportionate to the actual risks to human health from environmental problems?

A In terms of EPA regulations, let's take the areas where the most effort has been expended—the air and water programs. As far as the general population is concerned, there has been a tremendous reduction in the amount of air pollution exposure. The air pollution episodes of the 1950s and early 1960s just don't happen anymore; you don't hear much about water-borne diseases anymore, either. So these programs have been extremely successful.

Now we've moved on to other problems, particularly toxic materials. These are harder to deal with, not least because they are often site-specific, and we have to tailor programs to individual regions or areas where the problems crop up. So we're not talking in these cases about estimates of risk to the general population.

But if we know there is a risk people might be exposed to, then it's up to us to try to put together some sort of program which will reduce that risk, keep it at the lowest point in the range that we can.

Q There have been reports recently that acid rain may pose serious human health problems. Do the facts substantiate this concern?

A I don't particularly agree that the health effects cited are due to acid rain. People in the general population are exposed to particulate matter, some of which is acid aerosol, and some of that particulate matter causes some effects. But I really think of that in different terms than I think of acid rain itself.

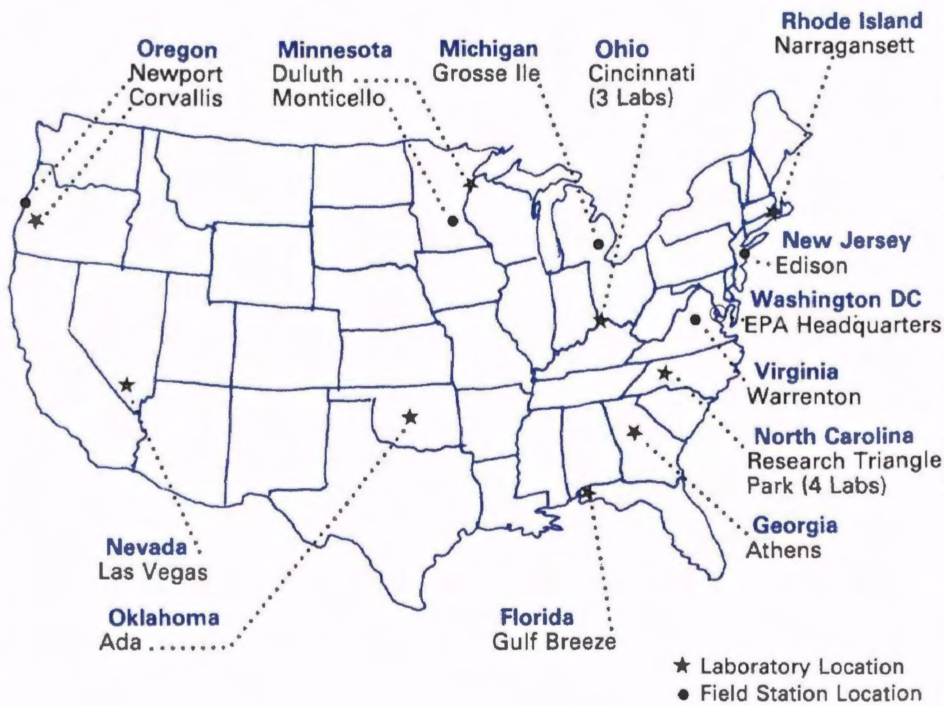
The Agency is not ignoring this as a problem. We're currently developing a document on acid aerosols that will be presented at a workshop in June and will go to the Clean Air Science Advisory Committee in the late summer. What's being argued is whether or not the effects we've seen represent acid rain effects. I don't believe they do.

Q Then would you say that the threat from acid rain generally is not as dangerous as it once appeared?

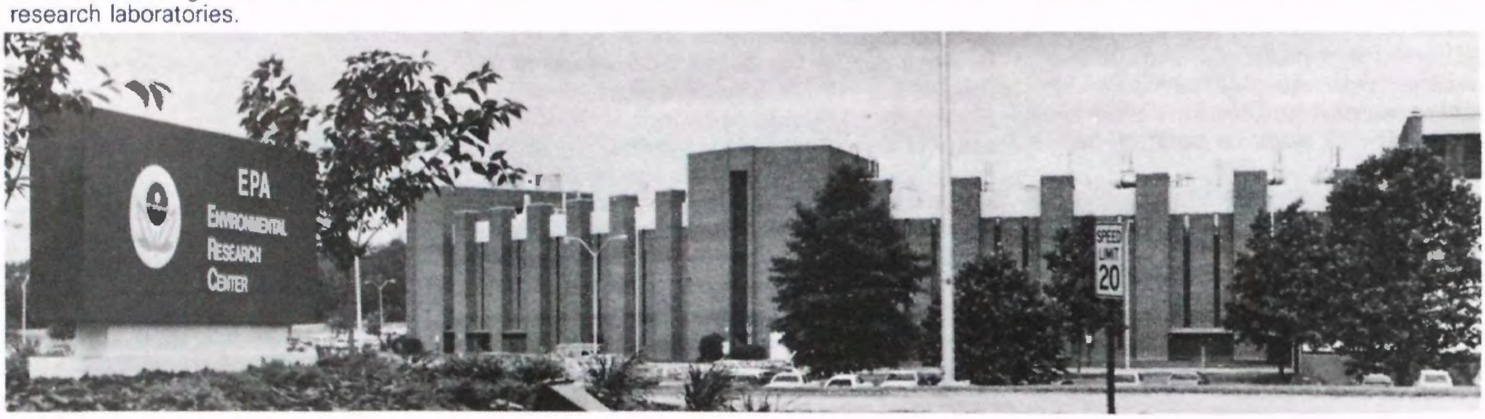
A I don't think there has been any change in the danger of the acid rain process as such. We still need to know more about it in order to determine what to do about it; we still need to continue with the research effort.

Some people have interpreted recent EPA lake studies to mean that there is no threat. What happened was that we gave our researchers the task of pushing some of our models and data as far as possible to see if we could produce estimates of the numbers of the lakes that might acidify over a period of time. And they did that. But to double-check what we had done, we had our assessment peer-reviewed. The reviewers felt that we had really pushed

Office of Research and Development
Laboratories and Field Stations



The main building of EPA's Environmental Research Center at Research Triangle Park, NC. The Center includes four of the Agency's research laboratories.



the data a bit too far, so that the number of acidified lakes predicted in 25 or 50 years was too uncertain for any definitive statement at this time. This was not a negative reflection on the acid rain program, but merely an assessment of the status of the predictive science given current scientific knowledge.

Q You cited peer review as a factor in the acid rain studies. What is the role of peer review generally, and how does it influence EPA research?

A Peer review is absolutely critical in the research process. No matter what research a scientist does, and what his results appear to be, those results are not usable by a regulatory agency until other scientists—specialists in the field—have reviewed them. They look at all aspects of the work, including the conclusions, and have to agree that the results are reasonable, based on the work that was done.

In addition to this classical form of peer review, we also have what we call research-in-progress reviews. These are conducted for the Administrator by the Agency's Science Advisory Board. These reviews look at ongoing research in areas that are of particular regulatory importance to ensure that our work is of the highest scientific quality. In fact, quality assurance in general is an area which we are heavily committed to.

Q Is EPA research published in scientific and professional journals?

A Yes, it is, and we encourage publication. Scientists are measured by the acceptance of their work by their peers. ORD is measured by the performance of our scientists. So publication in journals that require scientific review of submitted articles is a valuable form of peer review, too. Such publication is frequently a part of a scientist's job performance evaluation, and is key to internal awards and promotion.

Q Would you characterize EPA as a leader in environmental research? Should we play that role?

A You can't be the leader in every area, but I think there is no question that in some areas EPA has world class experts and is recognized as the place where some of the best and most innovative science in a given field is taking place. Although it is very important to develop that leadership and maintain it in some areas, it should not be the only measure of the research program in a regulatory agency.

What's important to EPA is that ORD manages to attract and hold on to scientists who are intelligent, competent, respected, and doing scientific work at the cutting edge of their field, and who are thus able to interact with scientists outside the Agency. Our scientists have to be aware of the work that is going on, and be capable of interpreting and understanding its implications for EPA's programs. This ensures that our decisions are based on the most accurate and current information.

Q Is it difficult to recruit scientists to work for the Agency?

A Yes, but we are very fortunate in ORD. We have a superb group of scientists across many scientific disciplines in our laboratories. Many of our research groups are world renowned. I don't doubt, though, that recruitment will continue to be a problem. Attracting the best scientists is a historical problem in government because we find it difficult to compete with aspects of the job environment in academia and the private sector. Universities provide scientists the opportunity to work on what they want, not on what is needed for a regulatory decision. Regulatory time pressures do not exist. The nature of academic life is different and can be very appealing. Then too, non-governmental organizations can often be more responsive in providing salary, research funds, and sophisticated equipment. So again, I think the loyalty and dedication of our scientists is admirable.

Q What work at the EPA laboratories do you consider particularly well done?

A Of course, I think the scientific quality of all our labs and work is extremely high. I mention just a few of the areas where our scientists have gotten recent national attention: the biotech work at Gulf Breeze; the fish tumor work there and at the lab in Duluth; combustion research at our engineering labs; inhalation toxicology work at our health labs in Research Triangle Park; the in-situ biodegradation research at Ada and the eco-region work at Corvallis; and the risk assessment guidelines developed by the Agency under the direction of the Office of Health and Environmental Assessment. And this is leaving many other exciting things out.

Q In terms of communicating with a non-scientific public, you've travelled extensively abroad. Are third-world countries with serious pollution problems in a position politically or technologically to take advantage of the results of EPA research?

A Yes, and it happens in many different ways. It happens by direct interaction between EPA people and the people in some of the countries. It happens by EPA's interaction with organizations such as the United Nations Environmental Program, or with World Health Organization programs to develop documents that are put out specifically to help third-world countries build their own programs.

It's really a technology transfer. Those countries, because of their culture, or where they are in their economies, may not be able to build the kind of programs that we have—the expensive kind of program we have here—but they certainly can trade off the risks they have and decide which they can tolerate and which they can't.

Q Do you see steps that would help to make ORD more effective in the long run, such as closing or consolidating some of the labs?

A Well, there are lots of arguments for consolidating laboratories, such as bringing programs together and not having overhead expense spread out the way it is at the present time. But I think it's unrealistic to think about accomplishing any of that.

So I accept the labs as a given and I think we ought to go ahead and build the best program we can within each of our labs.

As I mentioned before, I think a major step that will help ORD's program is to get the Science Advisory Board involved in planning longer-term research. The core capability we want to maintain within ORD relates to health risk assessments, to identifying ecological risks, to measuring exposure, and to taking care of risk reduction. I believe the expansion of the research program to give the regulatory efforts more solid underpinnings than they have at present will be good for ORD, but it will be even better for EPA. □

Reducing the Uncertainty in Assessing Environmental Risk

by Peter Preuss

Some people hate it; others love it! Some people see it as a smokescreen to mask political decisions not to regulate; others see it as an essential tool for making decisions in a resource-limited society. There are very few people who are neutral about the issue. I refer, of course, to risk assessment.

This tool, and particularly the quantitative aspects of it, have been the focus of controversy for many years. Yet, under both former Administrator William Ruckelshaus and current Administrator Lee Thomas, EPA has made a very strong effort to incorporate risk assessment into its decision-making process. Similarly, risk assessment has begun to play an increasingly important role in other federal regulatory agencies, and in many state regulatory agencies as well.

This heightened use of risk assessment has fueled controversy about the validity of using it, and has, at the same time, added a significant new component to the agenda of EPA's Office of Research and Development.

Risk assessment has been defined by the National Academy of Sciences as the use of available scientific information and reasonable scientific assumptions to evaluate the health risk to people from exposure to hazardous materials and situations in the environment. Risk assessment, in the Academy's term, consists of four parts:

- **Hazard identification** involves gathering and evaluating information on the types of health injury or disease that may be produced by a chemical and on the conditions of exposure (e.g. inhalation, ingestion, or skin absorption) under which the injury or disease is produced.

- **Dose-response assessment** describes the relationship between the amount of a chemical taken up by the body and the incidence or seriousness of the injury. This includes extrapolation from animals to people and from the high concentrations used in an experiment to the trace amounts likely to be found in the environment.

- **Exposure assessment** describes the kinds of people exposed to a chemical (whole populations, children, expectant mothers, etc.) and the magnitude and duration of that exposure.

- **Risk characterization** is a summary statement of the likelihood of injury or disease resulting from exposure to that chemical, and a description of the uncertainties associated with the assessment.

Each of these four components is based on current scientific thought, and utilizes chemical, physical, and biological data to estimate risk. In almost all cases, however, the scientific bases for assessments are global unifying theories, and these are often inadequate to deal with the specifics of a particular assessment.

For example, our assessments of the carcinogenicity of chemicals are based on currently accepted theories of how carcinogens act, and how they influence the genetic material in the incorporation and reproduction of information so that a healthy cell is turned into a cancerous clone. Nevertheless, our theories are generally incapable of explaining how individual chemicals act to produce a specific carcinogenic effect.

Similarly, while we use modern methods to measure concentrations of chemicals in air, water, and food sources, our exposure assessments are too imprecise to tell us the actual amount of a specific chemical to which a person has been exposed. This is in large part because pollutants continuously move through the environment and people do not stay in one place.

As a result of these gaps in our knowledge, theories, and data, we are required to use a series of assumptions in our assessments. These assumptions, coupled with the errors in our experimental data and our models, introduce rather large uncertainties into our assessments. These assumptions and uncertainties lie at the heart of the controversy about the use of risk assessment.

Perhaps a simple example would be useful at this point. Let us suppose that we have studied Chemical A in a long-term animal test and have found that it produces a significantly increased number of tumors, of several types, in both male and female mice and rats. Suppose, in addition, we had looked at the presence of Chemical A in the environment, and found traces of it in certain food products, in the ground water in several parts of the country, and emitted into the air from several manufacturing facilities.

In order to assess the risk to people exposed to Chemical A, we must first assess whether or not this substance is likely to be a carcinogen in humans (extrapolation from animals to people); then we must assess whether or not there is likely to be a risk at the low doses to which people are exposed (extrapolation from the high doses in the animal study to the trace amounts observed in the environment); and then we must assess the extent to which selected groups of people, or perhaps even the entire population of the United States, are exposed to this chemical (extrapolation from limited monitoring and emissions data). Other assumptions and uncertainties also underlie our risk assessments.

In response to this dilemma, the Office of Health and Environmental Assessment in EPA's Office of Research and Development has started a research program specifically designed to reduce some of the uncertainties in risk assessment. Currently, scientists are working to lay out the assumptions that are used in our assessments. A work group will review these assumptions and select those few that seem to be most critical to the process and at the same time are capable of being resolved by research. Once assumptions to be investigated have been selected, a research plan will be developed and implemented. This multi-year plan will go into effect in fiscal year 1988.

In the meantime, however, we have already begun a number of research projects in those areas that seem to be particularly important and urgent. These activities fall under two of the risk assessment components defined earlier, namely, dose-response and exposure assessment. Projects in the dose-response area deal with extrapolation from animal tests to projections about human health. From them, we hope to develop mathematical models for dose-response assessment that more closely parallel our current understanding of the toxicology of these chemicals. The extrapolation projects are examining chemicals for which data exist in both humans and test species (e.g., chemotherapeutic drugs and hormones). Our goal is to develop factors for extrapolation from animals to humans that, in the absence of human data on a chemical, could be applied to existing animal data for estimating human risk.

EPA's biological/mathematical modeling projects are in the areas of cancer and of reproductive/developmental toxicology. The intent of these studies is to integrate basic knowledge of biological and biochemical processes and data on the metabolic properties of the chemical with dose-response data. As such, so-called mechanistically based models can be derived that predict human risk more accurately.

One of the major uncertainties in exposure assessment is that we traditionally measure or estimate the concentration of chemicals reaching the body, but not the amounts taken up by the body and reaching the affected organs. Developing an understanding of this so-called "delivered dose" is a major aspect of the research. Some of the projects are examining how different exposure variables may affect the dose actually delivered to the individual and the occurrence of toxicity. Variables being evaluated include the influence of dose-rate over time and route of administration (ingestion, inhalation, skin absorption).

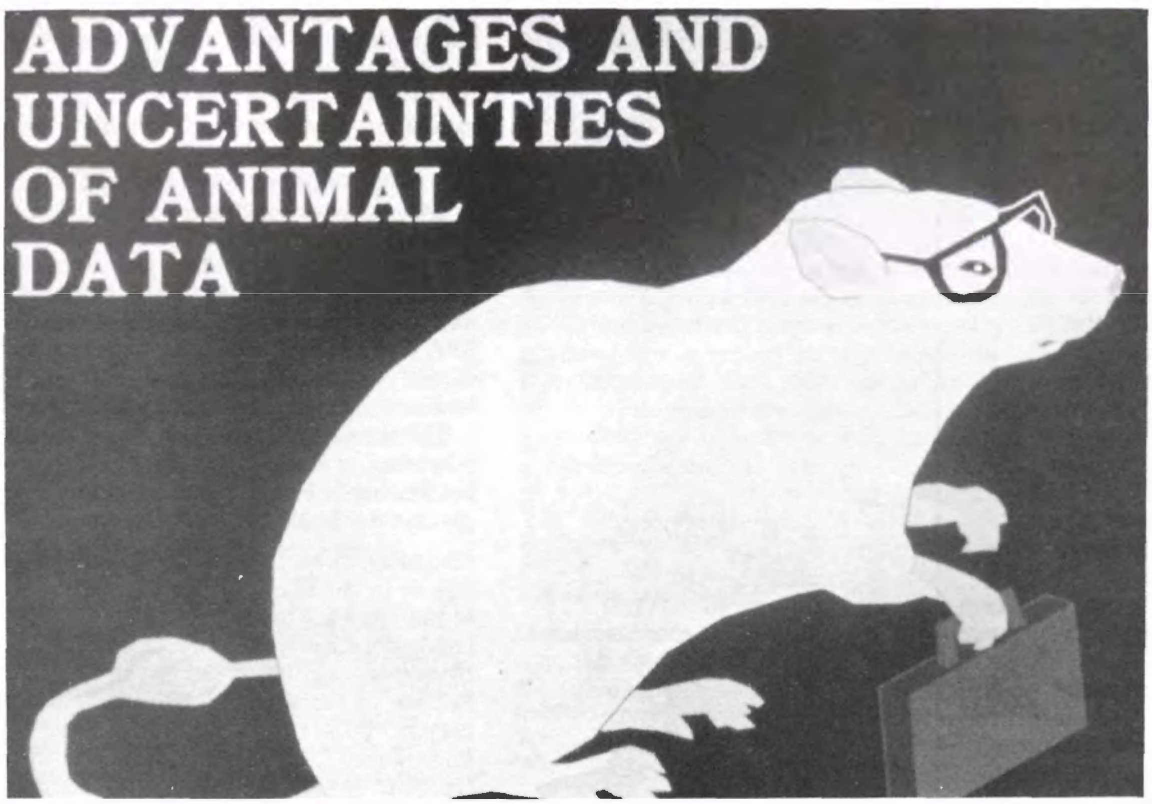
Other projects are designed to measure the metabolism of single and/or multiple agents once entry is gained into the body (pharmacokinetics) and the development of biological markers that could serve as equally valid measures of this "internal" dose (e.g., non-essential changes to DNA).

The remaining projects reflect attempts to increase the uniformity in the conduct of exposure assessments across offices in the Agency. Areas under investigation include the development of consensus validation criteria that could be applied to the selection and application of an exposure model appropriate to a particular situation, and the establishment of uniform strategies for evaluating the effects of short-term or periodic exposures.

These current projects will be integrated into the more systematic, coordinated program that is being developed by the Office of Health and Environmental Assessment to further EPA's objective of "Reducing Uncertainties in Risk Assessment." This program, if successful, will do a great deal to strengthen risk assessment for its role in the regulatory process. It will result in less reliance on "fall-back" assumptions, i.e., those assumptions that we use because of a lack of knowledge or information. It will create greater confidence in the results of the risk assessment process by generating confidence in the estimates produced. Finally, it will reduce the controversy about the validity and the utility of risk assessment as a part of the regulatory decision-making process. ☐

(Dr. Preuss is Director of the Office of Health and Environmental Assessment in EPA's Office of Research and Development.)

ADVANTAGES AND UNCERTAINTIES OF ANIMAL DATA



Most information for risk assessments is obtained through animal experiments which produce data used to estimate the health implications for humans. EPA's scientists are constantly trying to improve the accuracy of their projections from animal data to human health risk.

How Researchers Are Learning Ozone's Health Effects

by William McDonnell, III, and Donald Horstman

Running in the Los Angeles area on an August afternoon may well be the ultimate jogging nightmare, but some brave souls are actually volunteering to do it. Only they're not actually doing it by the side of the road in Los Angeles. These runners are volunteers in EPA's Health Effects Research Laboratory (HERL) in Chapel Hill, NC. Their track is a treadmill in a computerized, ozone exposure chamber, and their goal is to assess the human health effects of exposure to ozone under conditions which mimic those found in many urban areas of the United States.

Ozone is one of six "criteria" air pollutants for which the Clean Air Act requires EPA to set standards specifically protective of human health. A chemical oxidant and major component of photochemical smog, ozone can seriously affect the human respiratory system, and is one of the most prevalent and widespread of all the criteria pollutants.

Although the current standard for ozone is set at 0.12 parts per million (ppm), many areas of the country are not in compliance with this standard, and studies have shown that ozone is harmful at concentrations above the current EPA standard. To ensure that it provides adequate protection, EPA reviews the standard periodically. But to do this, EPA needs to identify precisely why, how, and to whom ozone effects occur.

There are several ways to do this, including animal, epidemiological, and clinical studies. Animal and epidemiological studies can be very useful for examining acute and chronic exposure effects, but standards to protect human health can not be based upon these alone. For that, we need clinical studies—and volunteers.

HERL's ozone study volunteers range in age from teenagers to senior citizens, and include students, faculty, and staff from local universities, as well as townspeople and medical professionals from around EPA's Chapel Hill research facility. Although some volunteer just to earn a few extra dollars or to have a thorough physical examination for free, many participants are in the health and scientific fields and have professional interests in the studies.

Regardless of their motives, however, all volunteers are rigorously screened for existing or potential physical and psychological problems. This screening includes a medical history, psychological testing, comprehensive blood tests, and a complete physical examination. To ensure that they understand their part in the studies, participants must study and sign a consent document which has been reviewed by the University of North Carolina Medical School's Committee on the Protection of the Rights of Human Subjects, and which explains any potential risks.

Exposure experiments vary, although ozone concentrations rarely exceed those of Los Angeles on a very smoggy day; most of the studies, in fact, are conducted at levels near or below the current standard of 0.12 ppm. Most exposures last from one to two hours, although some may go as long as seven hours in order to simulate exposure conditions in the real world. Because a given exposure level produces much smaller effects on people at rest, many of the experiments include exercise on a treadmill to simulate brisk uphill walking. Very fit athletes, such as marathon runners, also participate and run on treadmills.

Tests take place in stainless steel exposure chambers controlled for such factors as temperature, light, humidity, and pollutant concentrations, and equipped with redundant alarm systems to prevent any deviations. This facility is unique. It is highly sophisticated, using modern computer technology, allowing the most carefully controlled exposures possible as well as measurement of subtle physiological responses.

Before, during, and after exposure, the volunteers are measured for physiological performance and their subjective experience of pain, discomfort, and other symptoms. Investigators are present at all times during the experiments, as is a physician. Aside from a few faints and episodes of light-headedness, however, the ozone studies have been free of real emergencies—a tribute to the quality of the facilities and the careful planning and care by the investigators.

HERL's volunteers have already provided us with some very important facts. They've proved that exposure to acute ozone conditions—equivalent to 0.3 ppm, or what Los Angeles routinely experiences on a bad day—can cause chest pain, coughing, and shortness of breath, as well as limit people's ability to perform physically.

But the most surprising fact to emerge from the volunteer studies is that normal responses to ozone exposure vary enormously. Among healthy, very similar males 18 to 30 years old, for example, identical ozone levels caused acute discomfort for some, while not bothering others at all. Clearly, such a finding has important implications for setting the ozone standard, especially considering the law's requirement for an adequate margin of safety. It means that we need to study further the mechanisms by which ozone affects respiratory systems, as well as identify previously unsuspected effects and groups who may be more sensitive to ozone risks than others.

Those groups include not only joggers, but children, the elderly, asthmatics, cyclists, outdoor workers, and pedestrians—anyone, in fact, who exerts himself outside. The published data from research conducted in the EPA clinical facilities have been used directly to establish the national ambient air quality standard for ozone.

Thanks to the volunteers and Agency scientists at Chapel Hill, EPA will be better able to carry out its mission to protect the health and environment. □

(Dr. McDonnell is a research medical officer in the Clinical Research Branch at the Health Effects Research Laboratory in North Carolina. Dr. Horstman is chief of the Physiology Section in the same branch. Assisting in preparing the article was Mary Ellen Radzikowski, a program analyst with the Office of Health Research in EPA's Office of Research and Development.)

Creating Environments to Help Understand Marine Contamination

by Carole Jaworski

Each day in the United States, over 20,000 sewage treatment plants discharge over 20,000 chemicals into coastal waters, impacting more than 30,000 species of marine organisms. Yet very little is known about the long-term fate of these chemicals and how they affect the environment.

Laboratory or field studies cannot give a comprehensive view of what is occurring in this daily mix of seawater, chemicals, and life. Laboratory studies have limitations in their ability to capture a number of simultaneous processes that occur in ecosystems. Field studies are often limited by the difficulties in defining what is going on in this extraordinarily complex system.

For the past 10 years, the Environmental Protection Agency's Marine Ecosystem Research Laboratory (MERL) at the University of Rhode Island has been trying to get an experimental handle on whole marine ecosystems. The laboratory was established in 1976 in one of the country's first major attempts to study the effects of pollutants on marine systems.

The facility is largely a piece of plumbing. It consists of 14 tanks, 5.5 meters high, 1.8 meters in diameter, each containing 13 tons of seawater overlying one ton of natural benthos (sediment).

The tanks—called "mesocosms" by MERL researchers—are living models of marine ecosystems. Temperature, light, mixing, and water turnover are adjusted to closely simulate natural systems. When not deliberately manipulated, the biology and chemistry are largely indistinguishable from lower Narragansett Bay.

Not only do the tanks at MERL simulate the real world, but the system can be experimentally controlled and manipulated. This allows researchers to make observations not possible before.

During the past decade, MERL has studied the fates of various metals, hydrocarbons, and pollutants in the marine environment. The use of radioactive tracers has allowed researchers to track, with great sensitivity, what happens to various substances.

Eric Klos

Maureen McConnell, marine research specialist, lifts a plankton net out of a tank at EPA's Marine Ecosystem Research Laboratory at the University of Rhode Island at Kingston, Rhode Island. Conditions in the tank simulate those in Narragansett Bay.

Researchers were able to show, for instance, that oil spills do not stay long in the water "column" between the surface and the bottom. Oil either evaporates, degrades, or adheres to suspended particles and sinks with them to the bottom. Water, in the end, is a very transitory habitat for oil.

Over the last five years, studies at MERL have concentrated on problems of eutrophication, or undesired over-enrichment of the marine ecosystem.

Since the settlement of Rhode Island, the Providence River has received a steady stream of disease organisms, nutrients, metal, and more recently, toxic organic compounds. Most of these pollutants have settled to the bottom of the river and stayed there. The rest have flushed through the system into Narragansett Bay. The sediments remaining represent a vast reservoir of pollutants spanning some 350 years of contamination.

What is the impact of these sediments on the overlying water? Can a system with such a long history of pollution ever recover? If it can, how long would such a recovery take?

To answer those questions, researchers collected sediments from the Providence River along with measurably polluted sediments from mid-Narragansett Bay, and relatively "clean" sediments from the mouth of the bay. Tanks were filled with each of the sediments and an experiment was conducted for 21 months.

The results were unexpected.

It was observed that even though pollution sources were removed, the heavily impacted sediments remained polluted. What's more, they would probably remain polluted for decades. What was surprising, however, was that the water column would recover—and do so quickly. In spite of a steady stream of pollution for some 350 years, the study concluded that the river itself would recover in as little as four to seven years if pollution sources were abated.

And once clean sediment is deposited over a site no longer receiving pollution, it seals off older, more polluted sediments from the overlying water. A healthy "bottom community" can develop again—and healthy water—provided the sediments are not repeatedly stirred up.

This finding argues strongly that the money spent on efforts to clean the environment has been money well spent. Eons are not necessary for a polluted system to recover. It may do so rather quickly once pollution is stopped.

Following this study, research at MERL turned to the effects on the marine environment of various added amounts of nitrogen, phosphorus, and silica—additions such as would come from an ideal, 100 percent-efficient sewage treatment plant.

A series of nutrient loadings, ranging in amount from the average loading fed into Narragansett Bay to that of the inner New York Bight, was applied to the test beds.

At lower loads, production and the total amount of all trophic (food) levels was enhanced. At higher loads, massive shifts in species composition and community dynamics were observed.

The experiment was particularly valuable for indicating at what level of nutrient loading detrimental effects to a system can be observed. Although the experiment examined a wide variation of nutrient loadings, detrimental effects were observed only at the level currently impacting the Providence River. They were not observed when lower rates of nutrient loading occurred.

Many systems throughout the country are now approaching the same loading rate as the Providence River. But many other systems are, in fact, negatively impacted by a much lower rate due to stratification or slower flushing of pollutants from their waters. As a system is observed to be approaching a detrimental level, it becomes obvious that management decisions on alternate disposal sites or solutions need to be made.

Once MERL researchers knew the effects of pure nutrients, they turned to the problem of complex effluents, such as sewage sludge, on the system. There have been many efforts to assess sewage sludge disposal in the past, but the controlled mesocosm experiment at MERL offered an opportunity. In the laboratory tanks, the researchers could quantitatively assess the fate of sewage sludge components, their effects on plankton and other benthic (bottom) marine organisms, and the levels of sludge addition that cause detrimental effects.

As expected, the study found that the assimilative capacity of sludge was much lower than that of the nutrients per se, due to the demand for additional oxygen generated by carbon in the solid sludge. The experiment quantified the rate of sewage sludge addition to water that caused hypoxia, or low oxygen concentration, eventually leading to fish kills. The study concluded that, at summer temperatures, sludge amounts in excess of one gram of carbon per square meter per day will at first cause changes in zooplankton and benthic community structure and, finally, hypoxia, or oxygen depletion, in shallow water.

In addition, the experiment also discovered that sewage sludge settled to the bottom more rapidly than previously predicted. Hypoxia, therefore, was also likely to occur in deep water.

Results of the experiment were consistent with field studies. The detrimental effects that were observed were all due to the depletion of oxygen from the water column by sewage sludge addition. No direct toxic effects were attributed to the sludge treatments, but this may have been due to the short duration of the experiment or the generally lower concentrations of toxicity in the sludge examined.

The earlier nutrient experiment had raised an interesting hypothesis and, following the sludge study, researchers decided to test it. The nutrient experiment seemed to suggest that an abundance of silica in the sewer discharge led to more favorable progression of nutrients up the food chain, from tiny diatoms (algae) to more preferred species such as fish. When silica was lacking, less desirable progression seemed to occur, leading to such undesirable species as jellyfish. If this were true, researchers wondered, would it be possible to "control" eutrophication and guide the nutrition enrichment process in a direction leading to economic benefits from an improved fish catch?

The resulting experiment settled the question, but, unfortunately, not to the degree hoped. Adding silica did result in improved progression up the food chain to more desirable fish species, and did result in increased fish size. But the magnitude of the response was not sufficient to justify the effort. While the hypothesis proved correct, only a small percentage of change in fish size was observed. To be effective, a much larger increase in fish size would be required.

In 1986, MERL became part of a much larger three-level experiment looking at single species, mesocosm, and field studies of the same sewage effluent. The purpose of this study is to compare the three approaches for assessing toxicity of sewage effluent in marine environments and to verify single-species tests and their predictability.

The classic approach—and still the hallmark and workhorse of regulatory action today—is single-species testing for toxicity. The problem with this approach is that it can't predict what other components in an ecosystem also change due to sewage discharge. Mesocosm studies, however, can allow such prediction and at the same time add scientific credence to single-species testing. They can show when it is appropriate to use single-species testing and when it is not. Mesocosms can also test the validity of laboratory findings and determine what can or cannot be extrapolated to the field.

In addition, mesocosms are excellent mechanisms for testing mathematical models. While such models are well adapted to sensitivity analysis, they are not necessarily good predictors of complex interactions. Interaction, replication, and complexity are the forte of the mesocosm.

In the decade since the MERL was built, it has been a remarkable success. Two aspects of this success are of particular interest and use to EPA.

- First, it has offered the possibility of studying an ecosystem by changing various parts of it in a realistic and meaningful way, thus moving ecosystem research from being an almost purely observational science towards being an experimental one. As EPA is more aggressively concerned with protecting the environmental values, the importance of this research to EPA in general, and specifically as applied to coastal ecosystems, cannot be overemphasized.
- Second, the MERL can get ecosystems data on transformation, fate, and effects of pollutants in coastal ecosystems, thereby providing actual numbers that can be used by EPA and state permit writers, enforcers, etc.

EPA funding, augmented by the National Science Foundation, the National Oceanographic and Atmospheric Administration, and the Andrew W. Mellon Foundation, enabled researchers from different disciplines to be team players, with time to gain a true perspective of what a complex system like MERL can model.

Researchers from EPA; Woods Hole Oceanographic Institution; Cornell; the University of Rhode Island; the University of Connecticut; Dalhousie University, Halifax, Nova Scotia; the University of Stockholm; the Marine Biological Laboratory, Woods Hole; and the University of North Carolina; as well as other institutions, have already utilized the facility. □

(Carole Jaworski is a consultant at EPA's Marine Ecosystem Research Laboratory at Narragansett, RI.)

Scientists Take a Close Look at "Ice-Minus"

by Harold Kibby

One of the staples of science fiction is the invasion of Earth by new, alien forms of life. Even though nature seems to be constantly evolving new forms of life, there is considerable apprehension when this process is controlled by man: witness the public concern and legal action that preceded the two agricultural biotechnology field tests described in this article and put into action just this past April.

This problem is now upon us with the emergence of the science of genetic engineering into practical reality. Intentional modifications of the genetic structure of microorganisms has tremendous potential for human benefit, but will it also be accompanied by human or environmental harm? As with any new technology there are risks, yet with genetic engineering, even when the risks appear to be minimal the public concern is great.

This is illustrated by recent public hearings at Tulelake, CA, which preceded one of the first authorized test releases in the U.S. of a genetically engineered organism. Even though this particular instance didn't involve introduction of new genetic material—merely the removal of a gene from a bacterium that already exists harmlessly in nature in large numbers—fears ranged from food contamination to an outbreak of cancer.

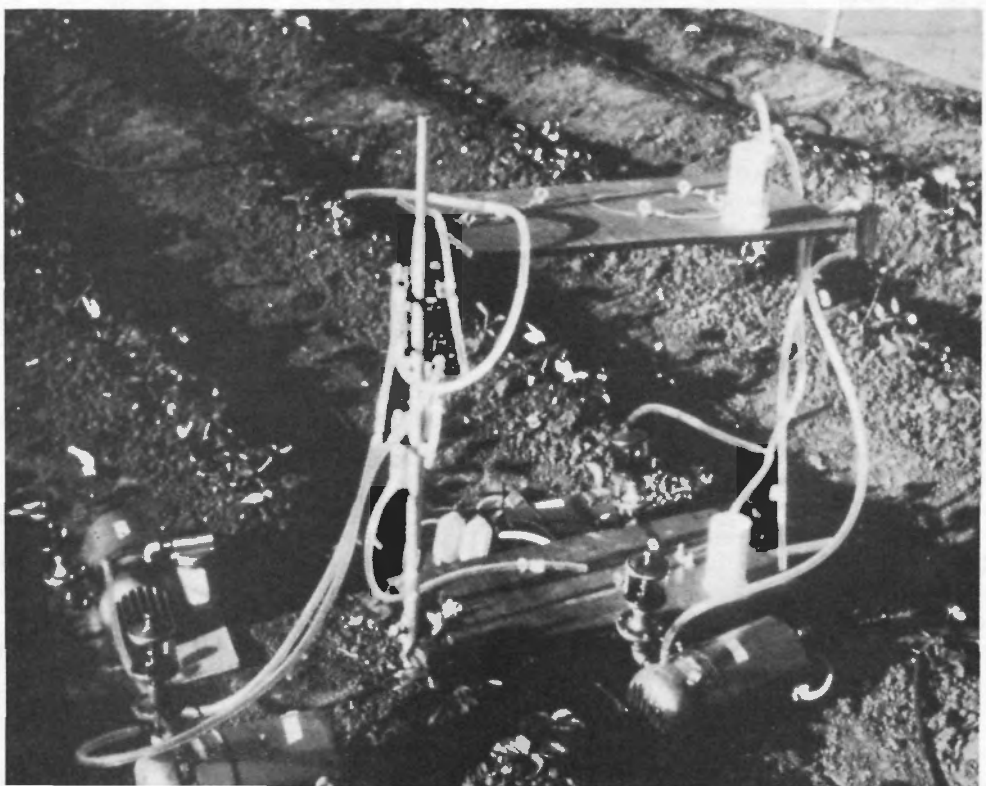
The source of all this controversy is an effort to reduce agricultural losses from frost. Many plants are sensitive to frost and cannot tolerate ice crystals forming within their tissues. The resulting damage is a significant problem to farmers growing many fruits and vegetables; thus, ice damage directly affects the price consumers must pay for agricultural products.

Scientific evidence suggests that frost on plants is formed by naturally occurring bacteria that live on the leaves and produce a protein in their cell membranes that enables them to serve as a nucleus or "seed" for ice crystals. Strains of *Pseudomonas syringae* are the most common ice-plus bacteria found on plants in the United States. Other common, naturally occurring bacteria such as *Erwinia herbicola* and *Pseudomonas fluorescens* also serve as nuclei of ice crystals.

During growth of *Pseudomonas* on plant leaves, some strains—known as "ice-minus" bacteria—naturally lose their ability to form ice crystals. The ice-minus bacteria occur in such small numbers that they cannot successfully displace the ice-plus strains on their own. However, if the normal population of bacteria on plant leaves could be replaced with bacteria that do not have ice nucleation genes, then frost damage would be reduced and much crop loss prevented.

To take advantage of this possibility, two groups of scientists, one at Advanced Genetic Sciences (AGS) of Oakland, CA, and the other at the University of California, Berkeley, identified the genes in *Pseudomonas* that cause ice formation and successfully altered them so the bacteria no longer form the nucleus of ice crystals. By genetic engineering, they created in the laboratory a strain of ice-minus bacteria nearly identical to those occurring in nature.

This was done by removing from the *Pseudomonas* a piece of chromosome containing the gene necessary for ice-plus protein synthesis. This piece of chromosome was transferred to a second bacterium, where a portion of the ice nucleating gene could be removed. The chromosome with the modified gene was re-inserted back into the original



EPA monitoring equipment is used to find out whether frost-deterrent bacteria are migrating from these strawberry plants into the environment.

Even though nature seems to be constantly evolving new forms of life, there is considerable apprehension when this process is controlled by man.

Pseudomonas, thus altering the genetic make-up of the original organism by eliminating only a portion of a gene.

Laboratory experiments demonstrated that these "manufactured" ice-minus bacteria prevent frost damage down to a temperature of about 23 degrees F. Normally, frost damage occurs at about 28 degrees F.

The controversy surrounding these bacteria erupted when both research groups applied to EPA for an experimental use permit to test the bacteria in the field, as required by the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), which requires pesticides to be registered by EPA. The altered bacteria are considered a pesticide because their intended use is to control the ice producing "pest," ice-plus strains of *Pseudomonas syringae*.

One could ask, why use genetic engineering to control frost when there already are conventional methods such as spraying water, burning smudge pots, or using wind machines? Each of these methods is effective under certain conditions, but each also has operational, economic, or environmental limitations. Spray irrigation requires large amounts of water and is ineffective when wind or other factors prevent continuous wetting of the plant; smudge pots burn fossil fuels; and wind machines require electricity.

The use of ice-minus bacteria does not involve adding "new" genes to the environment, or the creation of a new life form. Instead, it artificially creates a strain of bacteria by removing a piece of a gene. The resultant organism is nearly identical to the bacterium that occurs naturally.

Nonetheless, some citizens worried about how these tests would affect them. Concerns ranged from fear of increased cancer risk to the possibility of agricultural crops becoming contaminated with harmful bacteria. There is concern that crops from the test areas might be boycotted, with resultant economic losses.

There are also scientific questions. While it is controversial, some scientists believe that the ice-plus strains of *Pseudomonas* have several significant broader ecological roles, including influence on patterns of rain and snow, and possibly on the geographical range of frost-tolerant plants. Scientists know that the ice-minus and ice-plus strains have almost equal ability to compete in nature and that, in a competitive situation, the strain with the initial advantage in numbers is likely to become dominant for some short period of time. A few worry that, where there are low or non-existent natural populations of *Pseudomonas*, the ice-minus bacteria could proliferate and produce unknown environmental consequences. Other scientists contend that it is extremely unlikely that sufficient numbers of ice-minus bacteria will leave the experimental plots to become established as the dominant strain. Recently, a panel of expert scientists advised EPA that there was little if any risk involved in introducing these bacteria under test conditions into the environment.

Field tests are necessary to evaluate the effectiveness of the bacteria. Prior to last April, all experiments were conducted in the laboratory. It was not known whether or not the ice-minus bacteria would be effective in the natural environment. The final determination can be made only where the bacteria compete with a diverse array of naturally occurring bacteria under naturally occurring weather conditions.

EPA approved the experimental release of these organisms at two different locations. The release of ice-minus bacteria by AGS took place on strawberries near Brentwood, CA. The University of California released its bacteria on potato plants at Tulelake, CA. As part of the permit conditions, scientists from EPA's laboratories at Corvallis, OR, and Las Vegas, NV, are determining if there is movement of bacteria off the spray sites. A detailed plan was developed to determine how far downwind the organisms could be detected with air sampling units. Sampling was to continue for up to 49 days following the release, depending on whether bacteria were detected in the samplers.

A variety of sampling devices are being used, ranging from complicated mechanical samplers that allow

Laboratory experiments demonstrated that these "manufactured" ice-minus bacteria prevent frost damage down to a temperature of about 23 degrees F.

scientists to estimate the numbers of bacteria in the air over time to simple plates of agar that grow bacteria. Since plants can "capture" bacteria, portable trays of oats were also used to monitor the movement of bacteria. These plants have an additional advantage over conventional mechanical devices since they can integrate sampling over long periods of time.

Ice-minus bacteria are only one of innumerable bacteria that are being engineered for a myriad of uses. Many are naturally occurring microorganisms that are being released in large numbers into new environments; others are new forms of life genetically engineered for specific purposes. Genetically engineered microbes (GEMs) have tremendous potential for helping society. Because of the potential benefits, a large biotechnology industry has already emerged. However, until the last several years, little has been done to assess the ecological fate and effects of such engineered microbes. There will be increasing pressure on EPA to evaluate new biotechnology products in a safe, efficient, and effective fashion. Studies will continue to be needed that employ a variety of scientific tools such as simple laboratory tests, microcosm studies, and finally, when we believe that any risks are minimal, full-scale field studies. ▫

(Dr. Kibby is chief of the Toxics/Pesticides Branch in the Agency's Environmental Research Laboratory in Corvallis, OR.)

New Techniques to Project Acid Rain's Impact

by Raymond G. Wilhour

Lake in the Adirondack Mountains in New York State. Samples were taken of 155 lakes in the Adirondacks during EPA's National Surface Water Survey to determine how many in the region are acidic or acid-sensitive.

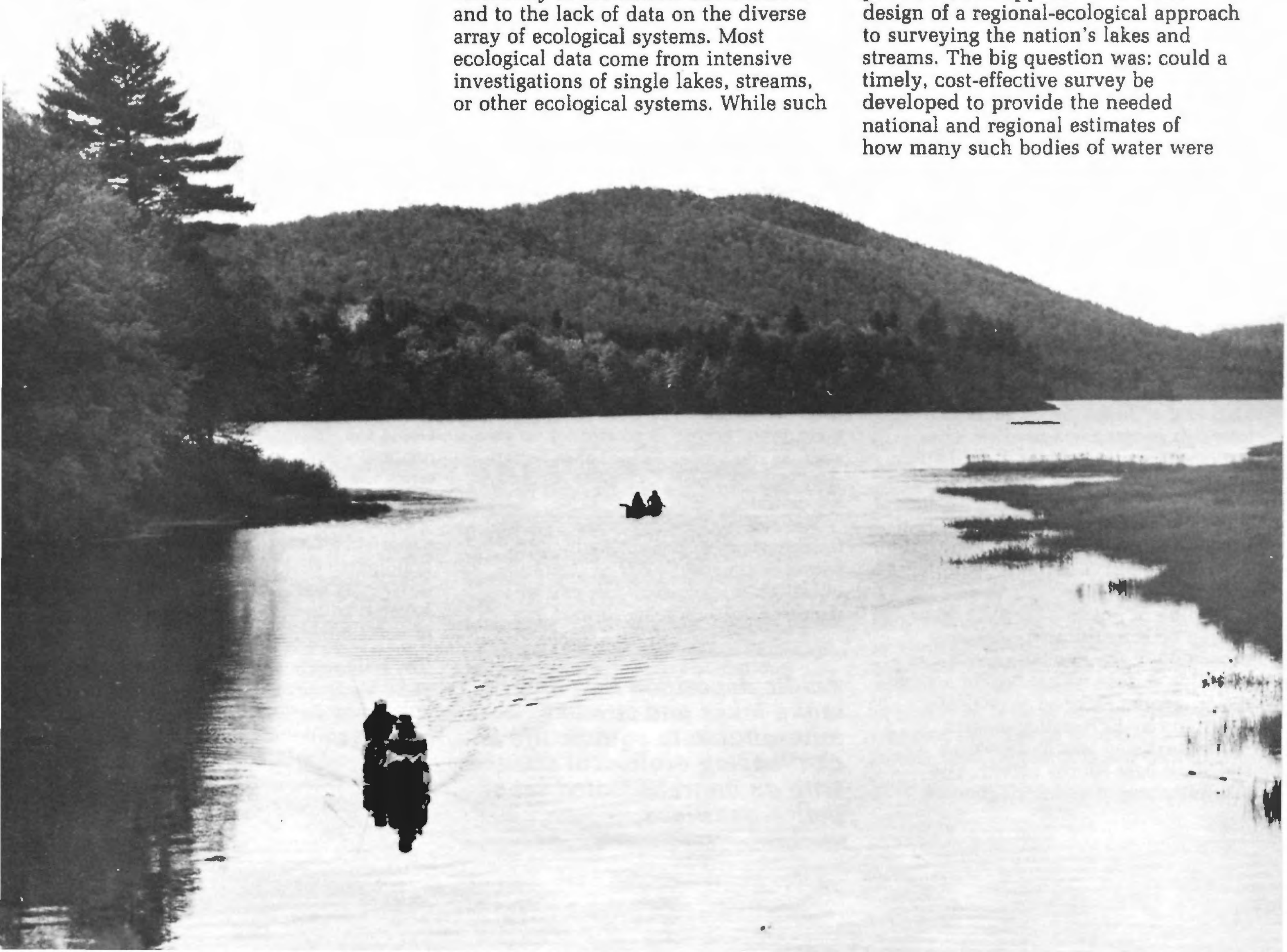
How many lakes and streams across the United States are acidic or sensitive to acid deposition? Where are they? And how many more are likely to be affected by acid rain if future levels of acidic deposition do not change? Environmental Protection Agency researchers using a new approach to risk assessment based on regional ecology are seeking the answers to these questions.

Acidic deposition that may make lakes and streams inhospitable to aquatic life is challenging ecological science with an unprecedented set of policy questions. The answers will affect regulatory decisions that could involve billions of dollars in pollution-control expenditures.

Although EPA has statutory responsibilities for protecting both the environment and human health, the Agency's approach to ecological protection is not as well-defined as it is for human health. This is partially due to the enormous complexity and variability of the natural environment and to the lack of data on the diverse array of ecological systems. Most ecological data come from intensive investigations of single lakes, streams, or other ecological systems. While such studies help scientists to understand how ecosystems function, they do not provide a basis for national or regional estimates of what resources may be at risk from man-made factors such as acidic deposition.

Scientists at EPA's Environmental Research Laboratory in Corvallis, OR, faced this dilemma when they were presented with a series of policy questions on the problem of acid rain and other forms of airborne acidic deposition. Most of the data available to them came from site-specific studies. It could not easily be applied to all the lakes and streams in a large region such as the northeastern United States or, for that matter, the entire country. The only traditional alternative for gathering such data was a statistically random survey of lakes and streams across the country—an enormously and prohibitively expensive undertaking.

The Corvallis scientists turned instead to techniques they were developing to deal with other water pollution problems, and applied them to the design of a regional-ecological approach to surveying the nation's lakes and streams. The big question was: could a timely, cost-effective survey be developed to provide the needed national and regional estimates of how many such bodies of water were



acidic or acid-sensitive? Their response to the question was to create the concept that became the National Surface Water Survey (NSWS).

The survey's objective was to describe the broadscale current impacts of acidic deposition on our nation's surface waters and to provide a basis for forecasting future impacts. This meant making measures on hundreds or thousands of lakes and streams, rather than just one or several sites as had been done in the past.

Although a regionally designed ecological study was not an entirely new idea, the Corvallis scientists along with a sister laboratory (Las Vegas) took several innovative steps to ensure that their approach would be more successful than previous efforts to collect comparable information on a regional scale. The ecological basis for their design was that biological communities, physical and chemical landscape features, and the chemistry of lakes and streams are naturally organized into areas or regions in such a way that there is greater similarity within a region than there is between different regions. Historical events responsible for these patterns include geological activity such as glaciation and erosion, and climate patterns. Collectively, these ecological elements determine the chemistry and biology of surface water. Although these ecological patterns are obvious to all of us as we travel across the country and see grasslands, forests, plains, and mountains, defining them scientifically is extremely difficult.

Step one in using these natural levels of organization to create the desired regional approach to the survey was the development of a Total Alkalinity Map of the United States in 1983. Corvallis geographers used regional ecological analysis methods to display broad areas that were potentially sensitive to acidic deposition because of their low surface water alkalinity (a measure of the water's ability to neutralize acid). The map gave policy-makers and scientists an indication of possible problem areas, but offered no scientifically defensible projection of the number of acidic or sensitive surface waters within a given region—data described as critically important by EPA policy-makers.

The next step was to develop a statistical base for the survey. The alkalinity map plus information on vegetation, geology, soils, and land use. After painstakingly interpreting and mapping these data for the entire United States, the scientists were able to define regions of the U.S. likely to contain the majority of low alkalinity lakes and streams. Regions such as the Northeast could then be further subdivided into subregions, such as southern New England, to better define areas of ecological similarity within which the lakes and streams survey would be performed.

Next, the lakes and streams in these areas were selected on a statistical basis so the scientists could ultimately estimate with a high degree of precision the total number of acidic and low alkalinity lakes and streams within each region surveyed. Water samples were collected during a very short period when conditions were relatively stable to provide an "index sample" that gave the scientists a clear picture of the water chemistry within a given region.

For example, 155 Adirondack Mountain lakes in New York were sampled during the NSWS study. Because of the way the lakes were selected, the samples were used by EPA scientists to estimate the chemical status of the 1,290 lakes in the Adirondack subregion. They concluded that at least 138, or 10.7 percent, are acidic. They also estimated that as many as 190 could be. This higher estimate is referred to as the upper confidence bound—probably the highest number. The upper-confidence bound magnitude varies from area to area, depending on the total number of lakes in the area and the percentage actually sampled. In the Southern Blue Ridge subregion, where 94 out of 258 lakes were sampled, scientists could be more confident of their statistical estimates, whereas the confidence bound is greater for an area such as the Upper Great Lakes, where they sampled only 141 lakes out of an estimated 4,515.

The regional approach is a breakthrough in our ability to apply sound ecological theory to scientific questions related to a large area or region instead of being limited to a single lake, stream, or local ecosystem. The National Surface Water Survey has shown that policy-makers, dealing with significant questions requiring regional or national ecological assessments, *can* be provided with the information they need for making regulatory and other risk management decisions. Specific answers to specific questions—where are the most acid-sensitive streams in the Appalachians located, for example—are available from the chemical data compiled by NSWS studies. And with those data we can further refine the regions of concern, create new subregions, or merge others. The information gained from these regional studies shows us how we can better define regions according to the problems we are trying to solve. NSWS, in fact, is the first regional application of this new approach.

This does not mean EPA is no longer interested in detailed research at individual sites. There will always be a need for studies of specific lakes and streams. But now we have a tool for determining how such a study site compares to other surface waters within a region or to select sites for additional research that best represent a region.

A marriage between geography, ecology, and statistics, the new regional approach to answering questions about acidic deposition is a major improvement over previous methods, and it needn't stop with acid rain research. Already, Corvallis scientists are using the ecoregion approach for practical applications at the state level. For example, an ecoregion map of Ohio provides Ohio water-quality managers with a picture of the state's natural water-quality patterns. The Corvallis loboratory has developed similar maps for Arkansas, Minnesota, and Oregon. Using the information shown about the regional patterns, the state officials can tailor their cleanup efforts for maximum effectiveness.

And, as scientists and managers gain experience with this new tool, it is anticipated that the regional approach to answering environmental questions will become an increasingly important part of environmental research. □

(Dr. Wilhour is chief of the Air Branch at EPA's Environmental Research Laboratory in Corvallis, OR.)

Acidic deposition that may make lakes and streams inhospitable to aquatic life is challenging ecological science with an unprecedented set of policy questions.

Surprising Results from a New Way of Measuring Pollutants

by Lance Wallace

Most people probably assume that the air inside their homes is better than the air outside a New Jersey chemical plant or a Los Angeles refinery. But according to a recent EPA study, this is not the case. The air in their homes is likely to be worse.

That's one of the surprising conclusions of EPA's five-year, Total Exposure Assessment Methodology (TEAM) study, which measured personal exposures to 20 toxic and carcinogenic compounds for 600 persons in seven U.S. cities. Included were two of the most concentrated chemical manufacturing and petroleum refining areas in the world: Bayonne-Elizabeth, NJ, and Los Angeles, CA. Yet even in these urban-industrial locations, and for every one of more than a dozen prevalent chemicals, the mean personal exposures exceeded outdoor concentrations by 200 to 500 percent. Validated by other researchers and by EPA's own follow-up studies, the results clearly suggest that the major sources of potentially harmful exposure are in our own homes.

Some of these sources have already been identified, although others remain unknown. For example, the TEAM study has shown that the major source of benzene and styrene exposures for about 50 million American smokers is the smoke they inhale from their cigarettes. This smoke also affects nonsmokers, because the air in smokers' homes averages 30 to 50 percent higher concentrations of benzene and styrene than the air in homes of nonsmokers.

Tobacco smoke is not the only culprit. The study also implicates a large number of consumer products and building materials as sources of household exposure, including such common items as paints, adhesives, carpeting, linoleum, wallpaper, and moldings. Other surprising compounds found in households include tetrachloroethylene from dry-cleaned clothing, para-dichlorobenzene from air fresheners and room deodorizers, and airborne chloroform released by normal domestic hot water uses such as showers, clothes washing, and cooking.

Another common source of exposure to harmful chemicals is the use of pesticides in the home. The initial results of an EPA study currently underway in Jacksonville, FL, and Springfield-Chicopee, MA, found that three out of nine homes sampled in Jacksonville had measurable levels of 13 to 14 pesticides in the air. The same study showed that at least 80 percent of people's airborne exposure is occurring in their own homes.

People can do a great deal to lessen their exposures without waiting for government regulations or major technical advances.

These major and previously unsuspected sources were identified by using small, personal monitors to directly measure the daily exposures of a representative sample of the population; the results of these measurements suggest a significant indoor pollution problem, with implications for both acute and long-term health effects.

More frequently found in offices than homes, acute effects are sometimes called "sick building syndrome", and may be caused by a mixture of organic compounds released by paints, adhesives, carpet, rubber and plastic products, particleboard, etc. In fact, some scientists have been able to reproduce sick building syndrome in sensitive persons by using a mixture of these typical chemicals. Although some people may be permanently affected by these acute reactions, and many are temporarily affected, it may be that the most important effect is not on health but on productivity. A nationwide poll indicated that 25 percent of workers in the United States believe that air quality in their workplaces affects them adversely.

Chronic effects are much more difficult to quantify. Some of the measured chemicals cause cancer in animals and may cause cancer in man. Benzene, for example, is known to cause leukemia in humans, and two recent studies have shown significantly increased leukemia mortality in the children of smoking parents. While we do not yet have satisfactory estimates of risks due to other chemicals found in the study, because of the lack of human studies to determine their cancer-causing potency, the observed personal and indoor exposures average three times greater than outdoor exposures.

These risks are not inevitable, however. People can do a great deal to lessen their exposures without waiting for government regulations or major technical advances. They can dispose of or store properly old paint cans, solvents, and pesticides, and minimize or eliminate the use of nonessential products such as room deodorizers. Dry cleaning can also be minimized, and freshly cleaned clothing can be hung outside to disperse the vapors. Those who must smoke can eliminate exposures to others by confining their smoking to one room vented to the outside.

If sources cannot be eliminated, there are methods for cleaning the air. Electrostatic precipitators can remove particles, and homes with central air conditioning may be able to use charcoal filters to remove such gases as benzene and tetrachloroethylene. Some homes are now being built of non-toxic materials and include separate ventilation systems for basement hobby shops, bathrooms, and other possible sources of toxic exposures.

Organizations are becoming involved, too. The American Lung Association distributes several pamphlets on toxics in homes and offices, and the American Society for Testing and Materials is developing standards to limit organic emissions from building materials. The American Society of Heating, Refrigeration, and Air Conditioning Engineers sets building ventilation standards. These are important first steps, but much remains to be done. □

(Dr. Wallace is an environmental scientist in EPA's Office of Research and Development.)

The Volunteers

"Volunteers needed for exposure study in Bayonne-Elizabeth, New Jersey."

The request was in a letter from then EPA Administrator William Ruckelshaus for volunteers to participate in the Agency's TEAM study of volatile organic compounds, a large-scale, statistically representative analysis of people's daily exposures to 20 known toxic and carcinogenic compounds. All they had to do was wear a vest containing a one-pound personal monitor for a day or so and breathe into a special spirometer.

Patricia Blau of Research Triangle Institute, a non-profit contractor for EPA, wearing a specially designed vest containing a personal air monitor and a battery-powered pump for collecting air samples.

Apparently, people were interested. About 4,400 households were initially interviewed for the New Jersey study, with 600 selected for participation after screening for age, sex, smoking habits, and occupations.

Because the vest monitors can collect and concentrate organic substances only for 12 hours at a time, sampling began in the evening. Each participant received a vest with a monitoring cartridge in it, the vest to be worn or left by the bedside for the first 12 hours. In the morning, study members replaced the exposed cartridges with fresh ones and also collected household tap water samples. Twelve hours later, the vests were picked up and tap water samples taken again. Finally, participants were asked to answer a questionnaire detailing their activities for the previous 24 hours and breathe into a spirometer. To establish the influence of outdoor air levels on personal exposure, some of the households had also been provided with fixed-site monitors in their backyards. These, too, were picked up at the end of the test period.

That was it. Yet these simple efforts confirmed the significance of indoor pollution as a source of exposure by yielding the startling information that, for some chemicals, indoor levels exceeded those outside by 200 to 500 percent.

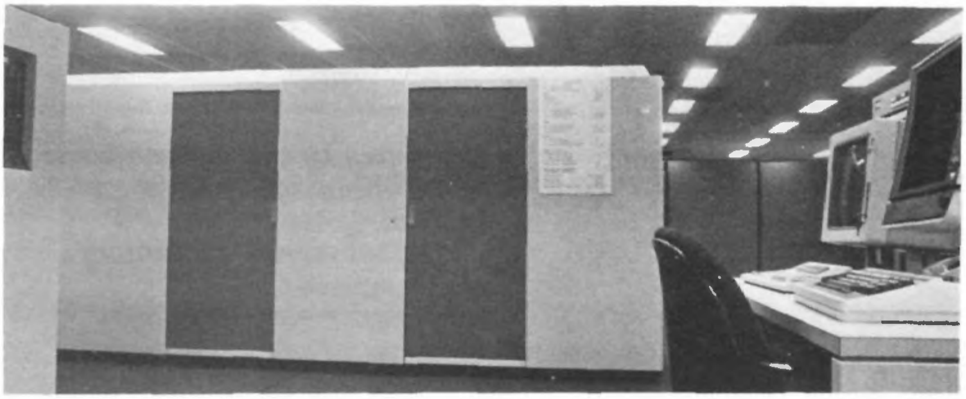
EPA so far has conducted TEAM studies on volatile organic compounds, carbon monoxide, pesticides, and particles. Developed specifically for the TEAM study, the miniature personal monitors have, for the first time, enabled the Agency to realistically "follow" participants through the day, sampling the air they breathe on and off the job, in and out of the house. These monitors are so extraordinarily sensitive that they measure chemicals at less than one part per billion, the equivalent of finding a single grain of sand in a 100-yard section of beach.

And not only are the monitoring instruments new, the selection of participants is now based on the extremely accurate statistical sampling methods first developed for political polling efforts.

This unique combination of engineering and social science will provide a solid foundation for future Agency efforts against indoor air pollution. □

Projecting Levels of Ozone Pollution

by Robert Lamb



The IBM 3090 supercomputer on which the EPA's Regional Oxidant Model (ROM) is run. The model is being adapted to project ozone concentrations in the northeastern United States.

In the early 1960s, the scientific techniques available to air quality engineers were primarily simple empirical formulas for estimating the rate of dilution of pollutants within a few miles of their source. They were capable of treating only primary air pollutants discharged directly into the atmosphere as waste products: sulfur dioxide and carbon soot, which are products of coal combustion, and carbon monoxide and lead, which are generated by the combustion of petroleum products in automobiles.

Methods of such limited scope are sufficient to treat the primary pollutants because, once they are airborne, their concentrations generally decrease steadily as a result of dilution, chemical transformation, and natural removal processes. Thus, the maximum concentrations are generally found in the immediate vicinity of their sources. Moreover, such pollutants tend to respond well to control efforts. A reduction in their emission rate results in a proportionate reduction in the atmospheric concentration. These attributes, plus the fact that the first major air pollutants were of the primary type, led to the early perception that air pollution is a localized phenomenon, controllable through regulation of local sources.

But when ozone emerged in the 1950s as a major new pollutant, it was the first secondary pollutant to become a significant problem. Secondary pollutants are substances like ozone that are produced in the atmosphere itself by chemical reactions among primary pollutants, the products of primary pollutants, and normal constituents of the atmosphere. Others in this group include peroxyacetyl nitrate (PAN) and the sulfates and nitrates that cause acid rain. Chemists are still trying to sort out the detailed chemical steps involved in ozone production. It is known that three basic ingredients are necessary: nitrogen oxides, which are among the primary pollutants emitted by combustion sources; hydrocarbons, released into the atmosphere through the combustion, handling, and processing of petroleum products; and sunlight. The nature of the process involved is much more difficult to treat theoretically than that of primary pollutant production. While a particular ozone molecule might owe its existence to a nitrogen oxide molecule emitted by a power plant and a hydrocarbon molecule from a dry cleaning establishment miles away, a molecule of primary pollutant can, in principle, be traced back to a single specific source.

The air quality engineer of the early 1960s had no technology available to treat pollutants as complex as ozone. Even after the basic chemical reactions responsible for ozone production had been established, the information could not be used in engineering studies because it was in the form of mathematical equations whose solutions were unknown. The equations, sometimes referred to as the governing equations, describe the joint effects of chemistry, winds, turbulence, sources, deposition, etc. Because they were so difficult to work with, it was not until computers became available in the late 1960s that the scientific knowledge embodied in these equations could be applied to engineering analyses.

Although computers cannot solve the governing equations themselves, they can solve specially formulated analogs, or models, of these equations. By the mid-1970s, two basic models, the Environmental Kinetic Modeling Approach (EKMA) and the Airshed model, had been developed for use by engineers in testing strategies for hydrocarbon and nitrogen oxides emissions controls aimed at reducing ozone levels. The EKMA model was developed in-house by scientists at EPA's Atmospheric Science Research Laboratory, the Airshed model was developed under contract to the same laboratory.

Both models are limited in their applicability to individual urban areas and both treat only the daylight hours. These limitations are largely a result of the old view that air pollutants, including ozone, are local problems correctible through the regulation of local sources. The ozone abatement policies in place today were formulated under this philosophy and engineered with the aid of the EKMA and Airshed models.

In the late 1970s, however, evidence from field studies and analyses of air monitoring data began to indicate that ozone is not a localized phenomenon after all. One important factor is that sunlight is required for ozone production. A mixture of hydrocarbons and nitrogen oxides emitted after sunset will not produce ozone until irradiated by sunlight the next day, and by then the mixture might have traveled 100 miles or more from its area of origin. And if the ozone is produced over another urban area, it can act to weaken the effects of any ozone control measures implemented there. If the mixture is over a rural or remote area, it can create an ozone problem that local emissions changes cannot eliminate because there were few, if any, emissions to control. Another possible contributor to the widespread nature of ozone is hydrocarbon emissions from plants growing on the earth's surface. It was established in the late 1970s that many species of plants emit hydrocarbons that promote the production of ozone in the atmosphere.

Anticipating significant impacts of these factors on the effectiveness of ozone abatement policies, EPA's Atmospheric Sciences Research Laboratory at Research Triangle Park,

ROM tracks the concentrations of 28 chemical species, including ozone, and 70 chemical reactions among these species.

NC, began work on the Regional Oxidant Model (ROM). This model is designed to provide a means of developing and testing ozone control strategies that will take into account the chemical and physical processes that are important in multi-day, long-range transport of ozone and its precursors, including plant-released biogenic hydrocarbons. ROM spans an area from mid-Ohio to Portland, Maine, and from Northern Virginia well into Ontario. This rectangular area is divided into 2,520 grid "squares," roughly 12 miles on a side. Each of these is divided into three vertical levels, or grid cells, of varying thickness that simulate clouds, variations of wind speed and direction, mountain effects, atmospheric inversions, turbulent mixing, and other meteorological processes. Within each of its 7,560 grid cells, ROM tracks the concentrations of 28 chemical species, including ozone, and 70 chemical reactions among these species. The rates of the reactions are functions of the local temperature, air density, humidity, sun angle, and cloud cover in each cell at each hour.

The land area within each grid square is partitioned into sub-areas according to land usage, e.g., urban land, agricultural land, deciduous forest, water, and five other categories. This information is used to estimate surface heat variation and terrain and building resistance to wind needed in calculating turbulence effects. It also helps to estimate dry deposition of each of the 28 kinds of chemical.

Emission rates of each primary chemical pollutant from both man-made and plant sources in each grid cell are also determined. Emissions from man-made sources are based on state and county inventories of fuel usage, traffic counts, chemical processing, electric power production, wood burning, and many other processes; emissions from plant sources are based on estimates of the dry foliage mass of 61 species of trees, 10 types of field crops, and two groups of grasses compiled for each grid cell from detailed Forest and Agricultural Service records. These biomass data are combined with empirical emissions factors for each species, and hourly temperature, sunlight, and cloud cover data to yield biogenic hydrocarbons emissions rates that vary according to local weather conditions in each grid square.

Finally, ROM also uses meteorological information: temperature, humidity, wind speed and direction, etc. These data are gathered from weather records taken during times when maximum ozone levels were observed.

Once all the input data are available, the computer begins producing values for concentrations of each of the 28 chemical species in each of the 7,560 grid cells for each simulated 30-minute time interval. To simulate one day, for example, the computer must perform nearly 100 billion computations and process tens of millions of data values. On EPA's IBM 3090 supercomputer, this task takes about two hours. The cover photo of this issue of the *Journal* is an example of the model's output, generated by the computer based on ozone concentrations predicted by the ROM.

Thus, the ROM is essentially a numerical analog of a scale model of the northeastern United States, allowing policy planners or engineers to manipulate emissions, land usage, and weather conditions in any desired manner to estimate their likely impact on air quality. The most common application is the assessment of the changes in ozone levels that would result from specified changes in hydrocarbon and nitrogen oxide emissions at one or more locations. Applications of this type are being planned to aid the development of emissions control strategies for the Northeast for the period after the 1987 ozone-level attainment deadlines.

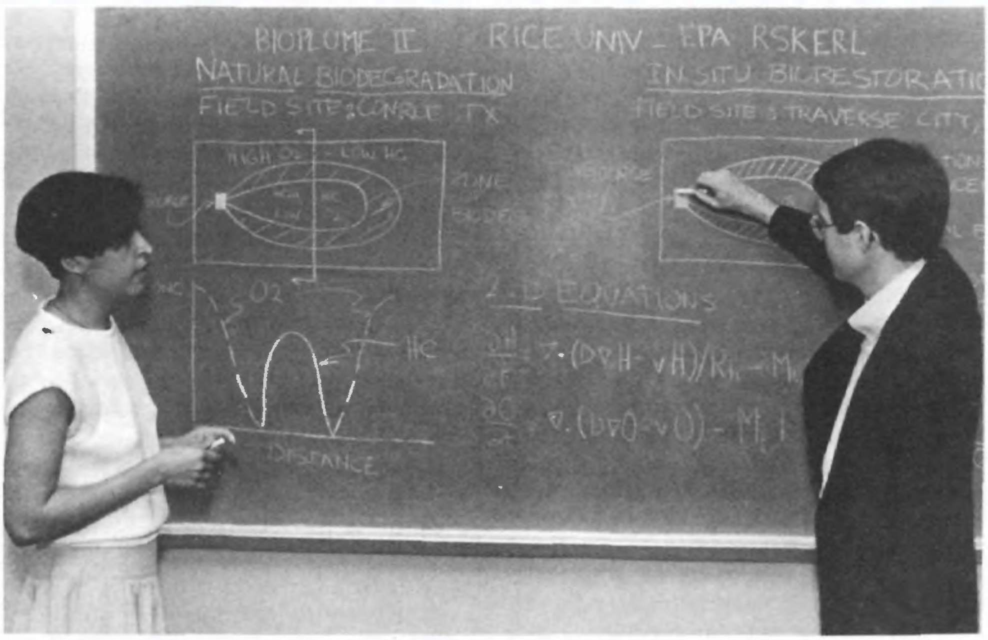
The ROM can also be used for diagnostic purposes. For example, in a given ozone nonattainment area, the model can estimate the fraction of the ozone that is generated from imported precursor chemicals and the fraction produced from local precursor emissions. Applications of this kind are underway to help guide post-1987 control strategy planning and to provide information that Congress can use in its work on the reauthorization of the Clean Air Act.

Perhaps the ultimate regulatory use of a model like the ROM would be as a component in a larger modeling system, one that could evaluate specified maximum permissible concentrations of each regulated pollutant and the cost of emissions controls for each source, and then calculate the least costly control strategy to satisfy air quality requirements. The mathematical techniques to build such a system are available today, but a computer at least 100 times faster than EPA's present supercomputer would be required to make any implementation feasible. Indeed, the future of large models like the ROM will be determined largely by advances in computer technology. □

(Dr. Lamb is a meteorologist with the National Oceanic and Atmospheric Administration on assignment to EPA's Atmospheric Sciences Research Laboratory in Research Triangle Park, NC.)

Learning to Use Microbes to Clean Up Ground Water

by John Wilson



Graduate students Hanadi Rifai and Charles Newell discuss computer modeling for the use of microbes in cleaning up contaminated ground water.

A growing national concern about pollution of underground water resources has encouraged Environmental Protection Agency researchers to search for new ways to remove contaminants. Microbial degradation of toxic wastes, combined with other remedial technologies, shows promise of offering less expensive and more effective ways to remove the pollutants.

We have studied the self-purification of lakes and rivers, and rely on natural processes to treat the wastes discharged into them. We have long relied on natural biological processes to treat domestic wastes applied to the land, either through septic tank discharges or by land farming. We now recognize that these same natural biological processes can destroy contaminants in soils and aquifers that result from leaks and spills or from disposal of hazardous materials to the land.

In a pristine aquifer, each glassful of water is exposed to more than a billion microorganisms that are busy extracting organic compounds in order to support their own lives. Their appetite keeps the concentration of biodegradable organic matter very low. When an aquifer becomes contaminated with something they can metabolize, the microorganisms quickly proliferate and gobble up the new source of food.

Occasionally, the microbes exhaust their supply of oxygen before the contaminants are removed. In the absence of oxygen, removal of biodegradable contaminants is often inhibited or stops altogether. As a consequence, the natural movement of ground water will spread the contaminants, thereby increasing the threat of human exposure.

Several important classes of hazardous wastes can be degraded biologically. Spills and leaks of petroleum products from underground storage tanks are probably the most common example; others include certain wood-creosoting wastes or refinery sludges, and coal tars left from the production of illuminating gas in the era before electric lighting. The latter are of increasing concern because most of the former sites of the old gas plants are still contaminated with these tars, and many are located in what are now the centers of our cities.

All of these wastes are primarily (or entirely) composed of natural organic compounds, mostly hydrocarbons, that are oily and only slightly soluble in water. They are considered hazardous because they often contain cancer-causing compounds such as benzene or benzo(a)pyrene, but they can be biologically degraded if oxygen is present.

When oily material is released to the earth, it drains through the unsaturated zone (above the water table) under the influence of gravity. Because it becomes trapped in the pore spaces, some of the oily material is left behind, while the remainder drains down to the water table. The water table moves up and down under the influence of pumping or annual cycles of precipitation. This fluctuation smears the oily material through the aquifer and allows laterally-moving ground water to become contaminated.

Contrary to the old adage, oil and water do mix. The more water-soluble components of the oily waste, such as benzene, can dissolve to some extent in water. As ground water moves through the contaminated area, the soluble components of the oily material dissolve, each according to its particular chemical characteristics, and a plume develops and moves toward a pumping well or some other point of discharge. This contaminated portion of the aquifer can serve as a source of ground-water pollution for decades.

When the plume of contamination leaves the source area, it is depleted of oxygen. However, diffusion and dispersion of the ground water ultimately bring the plume into contact with surrounding oxygenated water; when this occurs, the microorganisms' ability to degrade the dissolved waste compounds is restored. Under such favorable circumstances, many plumes—the areas of contaminated water—have a natural limit to their size. Since the rate of degradation is, effectively, the rate at which oxygen can be introduced to the plume, it is often possible to predict the ultimate size and location of the plume from the concentration of the contaminant and the supply of oxygen in the aquifer in which it is harbored.

EPA and state regulatory agencies need tools that can predict the maximum extent of existing plumes and forecast the effects of various remedial activities on their size. One such tool, a mathematical model called BIOPLUME, is being developed by EPA and Rice University. The model is based on several years of subsurface microbiological research led by our Ada laboratory, whose scientists have pulled together a multi-disciplinary team of microbiologists, hydrologists, geological engineers, analytical chemists, and computer scientists. The model will be supported by a manual which provides guidance on appropriate use of the model, and contains standard operating procedures to obtain the site-specific information required for its use. A version of the model, designed to run on an IBM AT personal computer, will be ready for general distribution late this year.

Although it is possible to reduce the size and life expectancy of contaminant plumes by the addition of oxygen and other nutrients, some may not require remedial action because natural processes alone are adequate. If the hydrogeology of a contaminated site permits these natural processes to be characterized, BIOPLUME can be used to address the fate of the plume. It can also be used to estimate the effects of remedial action technologies.

Although the scientific basis of biorestoration is well understood, actual application of the technology to hazardous waste sites is inhibited by a lack of information on its performance at field scale. There are a number of research projects now underway to evaluate the performance of this technology, to more accurately define the optimum operating conditions, to minimize costs, and to develop new approaches for biorestoration.

The basic concepts of natural or enhanced biodegradation to restore contaminated ground water complement more commonly used engineering approaches such as pumping and treating, excavation, or the creation of isolation barriers. The latter are most efficient and cost-effective in dealing with heavily contaminated materials, while biotreatment is most promising when dealing with lower concentrations. Because the two approaches complement each other, they will be most fruitful when used as tandem remedial action technologies. The challenge remains to identify the conditions under which each is most appropriate and the proper staging for their application. □

(Dr. Wilson is a research microbiologist at EPA's Environmental Research Laboratory in Ada, OK.)

Helping to Ensure Safety in Nuclear Testing

by Charles Costa

Every time Department of Energy scientists explode a nuclear device at the Las Vegas, NV, test site, Environmental Protection Agency personnel are involved in activities designed to protect people living in the area from any radiation releases which might take place.

Their actions are part of a monitoring program that began in 1954 with an agreement between the then Atomic Energy Commission and the United States Public Health Service (USPHS). The laboratory they created is now EPA's Environmental Monitoring Systems Laboratory (EMSL) at Las Vegas, one of 14 research facilities in the Agency's system. Its overall mission is developing, evaluating, and applying methods and strategies for monitoring the environment.

Radioactivity monitoring in public areas around the Nevada Test Site and other nuclear test sites was the initial focus of the laboratory's activities under the Public Health Service. USPHS scientists conducted environmental radiation monitoring, quality assurance, and research activities to monitor the Atomic Energy Commission's nuclear testing program throughout the 1960s. They also carried on a large biological research program.

When the laboratory came under EPA in late 1970, its overall mission was expanded to include research on monitoring systems for a variety of pollutants, but the radiation program remained a major mission and now operates under an interagency agreement with the Nevada Operations Office of the Department of Energy.

During the early days of nuclear testing, above-ground tests released considerable radioactive debris. But since 1963, all weapons tests have been underground. In the past 15 years, there has been only one accidental release of radioactive material into the air. This safety record notwithstanding, EPA continues to carry out a number of programs designed to minimize the likelihood and extent of offsite radiation exposure, reduce the risk to local residents should an accidental release occur, and facilitate risk communication to area inhabitants.

EPA participates in the decision process that precedes each test, providing the test controller with safety advice based on the Agency's review of the weather patterns, safety preparedness, population distribution, and related factors. At the time of each detonation, EPA staff are stationed downwind to measure and mitigate the effects of any accidental release of radioactive material.

Because ground water is the most probable pathway for radionuclides from underground tests to reach the public, EPA also conducts a long-term program of hydrological monitoring to assess the movement of radioactivity through the aquifers. The Agency routinely monitors ground water from 23 wells on the test site and another 52 beyond its boundaries.

To facilitate risk communication, EPA also has a highly visible Community Monitoring Network in communities around the Nevada Test Site. Designed to promote community-wide understanding of environmental radioactivity and its measurement, the program operates 15 stations in offsite communities. Each measures air samples for particulates and reactive gases, noble gases, tritium, gamma radiation exposures, and exposure rates. The data are provided to each community every week. Public meetings and training programs in community high schools are also part of this program.

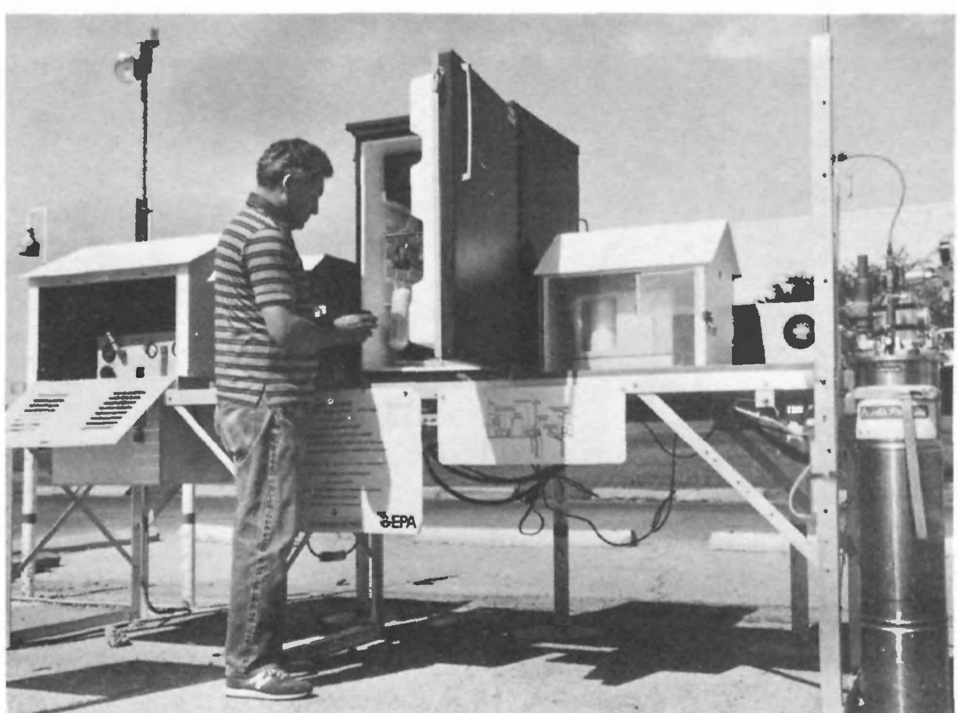
From Las Vegas, the laboratory also maintains a nationwide monitoring network of both continuously operating and standby stations. This network, which operated around the clock after the Chernobyl accident, also includes volunteers who routinely wear dosimeters, dairies or ranches close to the test site from which milk is sampled, and locations from which animal and food samples are taken and analyzed for radionuclides.

People living near the test site are monitored also as the ultimate means of determining internal radionuclide doses. These data serve as a baseline for comparing the amount of radiation in people around the test site with those elsewhere in the United States, and are especially important for making such comparisons at the time of an accidental release.

All of these activities are recorded in computerized data bases maintained for each type of radiation. A system is being tested for entry of the data directly from field-data cards at the time of collection. And, finally, EPA staff at the Las Vegas EMSL are completing computerization of historical dosimetry data for use in generating exposure/dose estimates based on complete geographic and chronologic information.

Back in the 1960s, Las Vegas researchers followed the movement of radioactive iodine in a cow's milk-generating system through a "window" in the cow's side. Now, with much more sophisticated technology, they are watching for radioactivity in air, water, humans, and animals, but the name of their game hasn't changed. It's still using research to protect our population from environmental contamination. □

(Costa is chief of the Nuclear Radiation Assessment Division in EPA's Environmental Monitoring Systems Laboratory in Las Vegas, NV.)



The Community Monitoring Station at Las Vegas, NV, is one of 15 developed to reinforce public confidence in the safety of the environment around nuclear test sites.

Tracking a Culprit in Outbreaks of "the Trots"

by Walter Jakubowski

Many Americans traveling outside of the United States take steps to protect themselves from traveler's diarrhea, otherwise known as "Montezuma's Revenge," "Delhi Belly," the "Purple Burps," and other more or less exotic and descriptive terms. Most of us have either experienced this malady or know someone whose dream vacation or business trip was disrupted by encountering one of several possible causative microorganisms in the local water supply. Consequently, the sophisticated American traveling abroad carries a variety of palliative remedies, carefully selects menu items, and scrupulously avoids drinking tap water.

In contrast, Americans living or traveling within the U.S. demand and expect safe drinking water from their taps. And Environmental Protection Agency research and related technical assistance is helping to ensure its availability.

Although the microbiological quality and safety of our drinking water may be superior to that delivered by suppliers in many other countries, waterborne disease outbreaks do continue to occur in the United States. Since 1970, there have been about 500 such outbreaks, resulting in thousands of cases of infectious disease. The causative organism most frequently identified in these outbreaks is a single-celled intestinal parasite known as *Giardia lamblia*. The gastroenteritis it causes is called "giardiasis", and it can be severe enough to require hospitalization. *Giardia* also infects birds, frogs, rodents, and other mammals, and because it is shed in their feces, all surface water supplies are potentially subject to contamination with *Giardia*. Since 1965, when the first incident was reported, there have been about 100 waterborne giardiasis outbreaks in various parts of the country.

Looking for clues concerning a gastroenteritis outbreak in Pennsylvania, Steve Waltrip, a biological technician with EPA's Health Effects Research Laboratory in Cincinnati, OH, collects a water sample under icy conditions.

Determining whether a particular outbreak of infectious disease is waterborne can be difficult and time-consuming. First, a sufficient number of cases must occur to bring the outbreak to the attention of public health authorities. Then, an epidemiological investigation seeks to discover the common sources of exposure, e.g., food, water, or person-to-person contact. Finally, if a common source of exposure is identified, steps are taken to interrupt the transmission process and to prevent a recurrence.

This can be quite complicated, and new cases may continue to develop during the investigation. Rapid determination of the route of transmission and the source of contamination is important if timely intervention and corrective action are to be taken. Urgency increases when a large community water supply is involved because many people can be exposed to the contaminant in a short period of time. An appropriate intervention in such a situation may be the issuance of a boil-water order, an action which could have considerable economic impact on restaurants, hospitals, bottling plants, and other businesses that use large amounts of water.

Prior to 1976, the organism had not been detected in a finished drinking water supply. Methods then available were cumbersome and difficult to use. In 1976, scientists at EPA's Health Effects Research Laboratory (HERL) in Cincinnati developed the first practical method for detecting microscopic *Giardia* cysts in water and successfully demonstrated the presence of the organism in finished drinking water. However, the technique requires an experienced analyst who may have to spend hours examining sample concentrates with a microscope, and even today, relatively few laboratories have this capability. Nevertheless, the HERL method, and subsequent modifications, is being used to assist authorities in the investigation of suspected waterborne outbreaks.

In April 1977, for instance, the laboratory staff at a hospital in Berlin, NH, note an increase in the frequency of giardiasis diagnoses over a short period of time. They notified the state health department and, through EPA Region 1, HERL provided assistance. Berlin gets water from two rivers. At that time, it also had two treatment plants—one constructed in 1939-40, the other a brand-new filtration plant that had just become operational.

At first, only the water from the older plant was suspect, but HERL investigators found that raw and finished waters from both rivers and both treatment plants contained *Giardia* cysts. It was subsequently determined that a design flaw in the new treatment plant allowed some unfiltered water to mix with filtered water before it entered the distribution system. The timely results obtained by EPA allowed water supply and health officials to make informed decisions on a plan of action to end the outbreak of waterborne infections.

Another example of HERL technical assistance occurred in the winter of 1983-84, when about 250,000 Pennsylvania residents were advised by health authorities to boil their water because of concerns about *Giardia*. Again, the HERL-Cincinnati laboratory was requested by the Pennsylvania Department of Environmental Resources through EPA Region 3 to analyze for cysts. Numerous water samples from several communities were examined, and the results aided in determining which supplies were at risk and in evaluating the utility of corrective actions.

In another kind of technical assistance, HERL scientists participated in workshops in Pittsburgh and Boston to help train staff in other laboratories to do *Giardia* analysis. Training was also given to microbiologists at the Region 1 and Region 10 laboratories to give those regions capability for doing the test.

Giardia continues to be a problem, especially in unfiltered surface water supplies or where filtration is improperly practiced. Control of waterborne giardiasis was a primary concern of the authors of the 1986 amendments to the Safe Drinking Water Act. These amendments require EPA to develop criteria for the filtration of surface water supplies. Implementation of the filtration regulations, which are now under development by the Office of Drinking Water, should decrease occurrence of waterborne disease and maintain consumer confidence in this vital resource. HERL investigators continue to develop new methods for detecting, identifying, and enumerating microorganisms in water. □

(Jakubowski is a microbiologist with EPA's Health Effects Research Laboratory in Cincinnati, OH.)

Sharing What We Have Learned

by Edwin Johnson

EPA invests millions of dollars each year, first in research and development, and then in technology transfer of the results. The investment more than pays for itself in terms of improving the scientific and technical bases of this country's environmental protection programs. EPA also benefits from exchanging information with other developed countries, either directly or through such organizations as the United Nations and the Organization for Economic Cooperation and Development (OECD).

None of this should be surprising. However, the relationships between EPA's research and the developing world do have their surprising aspects.

Pollution problems in developing countries are not all the same. Some countries lack the resources to develop and implement necessary pollution control measures; others are experiencing significant environmental problems because their rapid development has not been accompanied by appropriate environmental safeguards. Yet both kinds may enjoy the benefits of EPA's research, although each provides unique challenges.

The first group of nations suffers more from the lack of development than because of it. They face the historic problems of domestic sewage contamination of surface and ground waters, contaminated drinking water supplies, air pollution in urban areas, and inadequate disposal of trash and garbage. We've learned how to correct many of these problems over decades of experience and research in this country. But given their very limited resources, how can poor countries take advantage of this expertise? Clearly, it makes little sense for EPA to send documents or technical personnel to countries without the resources to implement solutions. EPA believes that the most effective way to assist these countries is to work through international funding

Part of the pollution problem India faces in the famed Ganges River. EPA is helping India in an effort to control the pollution.

organizations, such as the U.S. Agency for International Development (AID), the World Bank, or other multilateral development banks, whose mission is to provide developmental aid.

On the other hand, countries whose environments have been damaged by development often need to obtain technical assistance in repairing the ravages of rapid industrialization, and guidance on how to avoid such problems in the future. In such cases, EPA often works directly through a bilateral agreement, helping local experts deal with their problems and take advantage of over 20 years of experience and research in the United States.

The Agency is committed to helping developing countries with environmental problems in ways that recognize their individual social, economic, cultural, and other needs.

In India, for example, EPA is contributing to a multi-year program to clean up the Ganges River, a project initiated by Prime Minister Gandhi shortly after he took office. To date, six teams of EPA experts have traveled to India to work with their counterparts in assessing the problems, planning a program to reduce Ganges pollution, and helping plan the implementation of pollution-control measures for India's holiest river. Already, numerous workshops have been held in various Indian cities. The Ganges project, however, is just part of a broader series of activities underway under the aegis of the Indo-U.S. Subcommission on Science and Technology, whose activities range from environmental medicine and toxicology to natural area preservation.

In neighboring Pakistan, there was a serious problem with pesticide contamination. Stocks of aging pesticides in leaking containers had been left throughout the country in hundreds of small shops and storage areas. When pesticides were moved out, the contaminated quarters were often used as dwellings. Although the health hazards of this situation were well recognized by Pakistani authorities, the government and the pesticides industry could not agree on how to dispose of the material or who would pay.

EPA was asked to assess the situation and make recommendations for disposal. A team including an EPA pesticides disposal expert, an EPA economist, and a private-sector professional visited Pakistan and recommended a disposal option for possible funding by AID. EPA's research and practical experience with the disposal of toxic materials made this contribution possible.

In Brazil, EPA worked with the U.S. Conservation Foundation, a nongovernmental organization, and a group of international consultants to help the Saõ Paulo state regulatory agency (CETESB) resolve a critical air pollution problem. Industrial air pollution had devastated a tropical forest on the coast, which in turn led to severe landslides from the weakened surface of the Serra Do Mar mountain range. Our approach was not to dictate solutions to the Brazilians but rather to help sort through the array of options they had already identified. The team of consultants made recommendations on the good points of Saõ Paulo's proposed abatement program and suggested future directions for the program.

The experience was so positive that both governments expressed a desire for consultation and training on a continuing basis. CETESB is administering a World Bank loan provided for creation of pollution-control equipment in the state. The Bank has stipulated that a substantial percentage of the original amount, plus a portion of the loan payback by industrial polluters, be used for research, development, and training. Through its agreement, EPA will make available its expertise and CETESB will pay for the expenses of our staff.

In China, EPA Office of Research and Development scientists are working in a village to study the effects of cooking smoke on human health.

In China, EPA Office of Research and Development scientists are working in a village to study the effects of cooking smoke on human health. Such work will help the Chinese improve the safety of hazardous environments, and will help us to evaluate the implications of our own indoor air research program.

The International Registry of Potentially Toxic Chemicals (IRPTC), a branch of the United Nations Environment Programme (UNEP) located in Geneva, Switzerland, provides computerized information on hundreds of chemicals. Through this organization, EPA can share with developing countries data on the risks associated with known and potentially toxic materials. These data come not only from EPA's own research, but also from research and other investigations that EPA requires of certain industries.

EPA provides similar information, but in more detail and more specialized ways, through the International Programme on Chemical Safety (IPCS), a joint program of the World Health Organization (WHO), the International Labor Organization, and UNEP, which is administered by WHO. Environmental health criteria documents produced in draft by EPA as well as other institutions are provided to the IPCS to be critiqued and modified based on international peer review. The resulting documents are intended primarily for developing countries.

Pesticide data are reviewed by WHO and the U.N. Food and Agriculture Organization (FAO) through the Joint Meeting on Pesticide Residues. This provides not only international review of toxicological and residue data for developing countries, but also establishes Maximum Residue Limits for pesticides on commodities in international trade, thus informing developing countries of standards that they may be required to meet in trading with other countries, and of limits they might apply to their own imports of food. In addition to supplying written documents, EPA technical experts participate regularly in these scientific forums.

Such a list could go on and on, but the one common element is that *both* the United States and the other countries benefit from interaction. Our scientists gain knowledge of pollution situations that they might never see in the United States, thus dramatically broadening their range of experience and allowing them to gain important scientific information. They also gain perspective on alternative approaches to dealing with problems that we face here. Frequently, the information or insights gained through the program have helped our scientists find more efficient ways of dealing with domestic problems. In the long run, this cooperation helps some other country or distant village, or even some aspect of our own environment; it also allows our scientists to work in a larger arena in their efforts to help make this world a better place in which to live. □

(Johnson is Director of the Developing Countries staff in EPA's Office of International Activities.)

Thomas Talks about His Goals for EPA


Steve Delaney

Lee M. Thomas

On February 24, 1987, at a Senior Executive Service Forum in Baltimore, Lee M. Thomas talked informally to EPA managers about the "Seven Management Themes" that will give direction to the Agency in the years ahead: 1/ risk reduction; 2/ balancing environmental gains against other goals; 3/ environmental federalism; 4/ better environmental science; 5/ negotiation and consultation; 6/ enforcement; and 7/ human resources.
The following are excerpts from Thomas' remarks:

"As I have worked with EPA over the past four years, I have found that we all have to struggle with very difficult problems. Some we are handling very effectively. Others we need to talk through to see if there are better ways we can deal with them.

"That's the reason for our session here in Baltimore. I'm hoping that we'll arrive at new ideas by meeting and talking through some of our major problems.

"EPA has made a lot of progress in a lot of areas since it was founded in 1970. But the Agency's early achievements differ in fundamental ways from what I expect its future achievements to be. A different frame of mind—and a different management tone—are needed if we are to make a successful transition to the needs of the late 1980s and the 1990s."

Risk Reduction: *EPA's basic mission is to reduce the level of risk to health and to the environment posed by pollution. To that end, the Agency will focus its resources, and those of society at large, where pollution causes the most damage.*

"One of EPA's major challenges in the years ahead will be to sustain the progress we've already made in environmental protection throughout this country. There have been significant reductions in criteria pollutants, and massive cleanups of waterways and lakes. A major system is in place for managing hazardous waste in the United States. We are tightening controls on toxics and pesticides much more systematically than we have in the past.

"How do we maintain that direction, sustain that progress, and, at the same time, confront all the complex new challenges before us? We're going to have our hands full juggling all these tasks.

"I think that even in sustaining the progress we've made, we're going to be challenged to talk about the scientific basis of the direction we've come, the priorities that have guided our past progress. For instance, on a basic pollutant like ozone, we worked and set a standard early on, then reviewed the standard several times. The result was significant progress on that pollutant for 15 years. But that doesn't change the fact that we're going to be challenged hard over the next year about the scientific basis for that standard and the benefits of new ozone controls we're trying to put in place.

"Few risks need containment as much as toxics. Toxics dominate our time, and, I believe, will do so increasingly in the years to come. Unfortunately, however, we can measure toxics better than we can manage them. We can find parts per trillion and quadrillion of certain pollutants, and yet we really don't know what it means as far as risk is concerned once we find them.

"The existence of these data presents a great challenge to EPA managers, since it is up to us to decide what risk-reduction actions it calls for.

"The whole area of risk reduction is greatly complicated these days by the problem of cross-media pollution: cases where a contaminant we are trying to eliminate from one medium winds up causing damage in another. We are becoming increasingly aware of cross-media impacts in every aspect of our work, but as yet, we have not developed a systems approach so we can deal with them effectively."

Balance Environmental Gains Against Other Goals: *Environmental protection actions should be designed to achieve the greatest social benefit. The Agency will strive to manage its resources to achieve the greatest overall benefits for the public.*

"Regulatory costs are going up. Every day we are seeing this. The first 95 percent of pollution we have brought under control. As we work on the last five percent, it is going to cost us a lot more than the first 95. Those last few increments won't bring us nearly as much environmental benefit, for the money expended, as the first increments.

"We can already see the impact of economic considerations in a number of EPA programs. Look at the Waste Management Program just since I've been with EPA. We have been moving dramatically to improve waste management in this country. We're trying to move away from land disposal of hazardous waste, and we're pushing waste reduction and waste minimization. But those of you who follow the waste-management industry know that it's having a hard time adapting to the economic impact of EPA's new regulations.

"But how much further should we go in making people spend a lot of money on waste management? That's a question we're going to have to answer. I think we will be questioned hard about the impact of our regulations and what we hope to achieve with them.

"EPA clearly has the broadest and deepest regulatory authority of any federal agency. People joke: From the washroom to the boardroom, EPA is there. Well, in fact, that is the case. We cover it all. People are amazed when we get up and talk about the full range of statutory authority that backs up our regulatory efforts.

"But we have to back up that authority with good judgment. We need to fully understand the impact of that authority, and be ready to explain why the exercise of that authority is justified in particular cases.

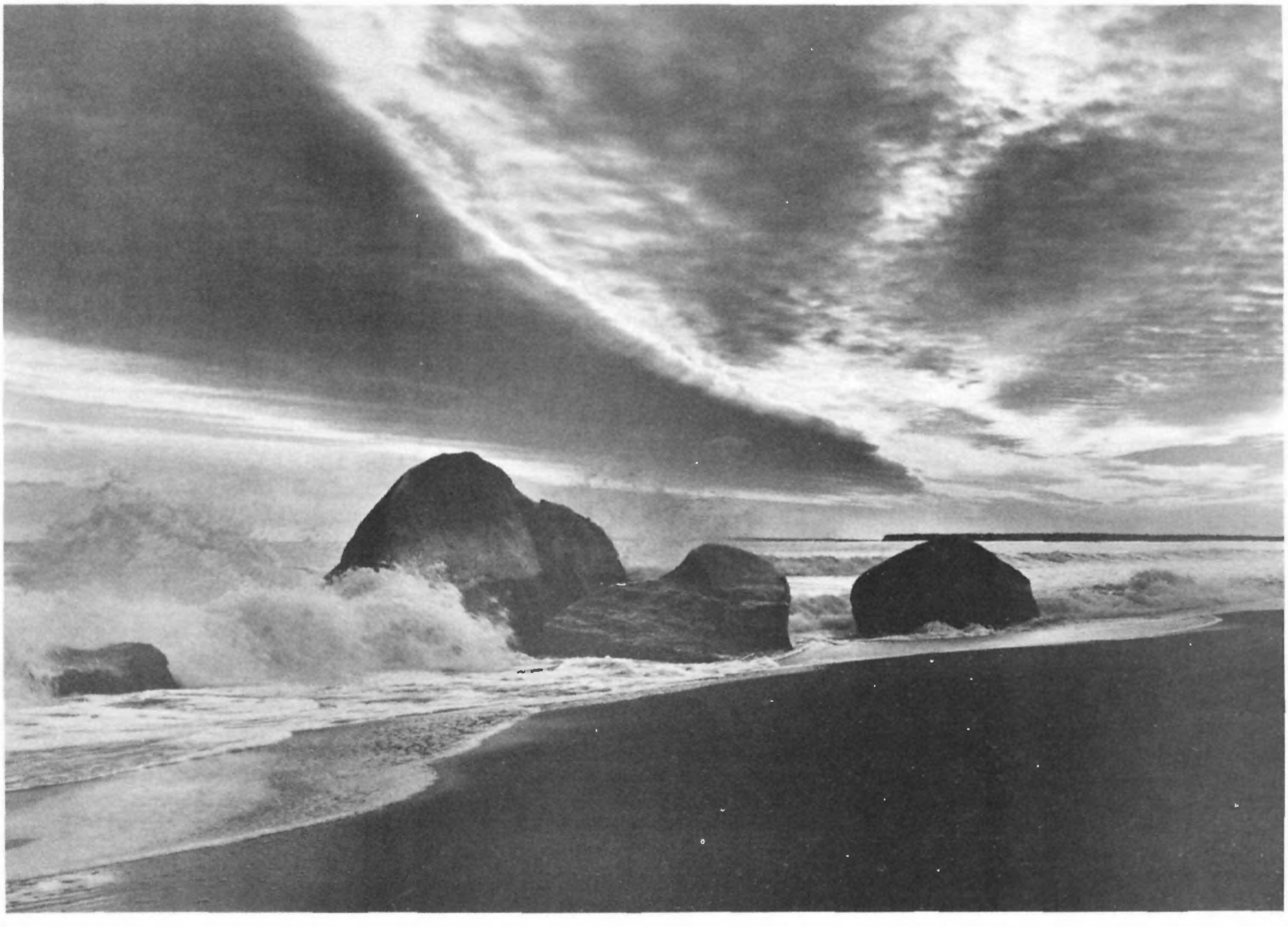
"For example, when we talk about ground-water cleanup, and we say we're going to spend this much money for this level of protection, we had better be prepared to explain the reasoning behind our decision. We are going to be pressed for answers to tough questions: Why didn't we opt for some greater—and more expensive—level of protection, and why didn't we opt for a lesser and cheaper level?

"Economics is going to be a major and a growing part in future discussions we have with the public, and with the people in the White House and on Capitol Hill who oversee what we do.

"So we had better be prepared not only to talk about what the impact is, but also about why we think a particular level of protection is appropriate—or inappropriate, what environmental benefits we expect to accrue from it, where we're prepared to go ahead now, and where we feel we should go in the future."

Environmental Federalism: *We recognize that each level of government has a proper role in public health and environmental protection, and that concerted and coordinated efforts of federal, state, and local agencies will best serve the public interest.*

A splendid view of a beach. Such isolation is no longer enough to protect areas from pollution. According to EPA Administrator Lee Thomas, environmental issues such as climate change and stratospheric ozone depletion now transcend national boundaries and call for global solutions.



M. Zide for Woodfin Camp & Associates

"Environmental federalism is basically a matter of sorting out responsibilities among different levels of government. And they must be sorted out more and more clearly as our various programs move to management at a state and local level.

"EPA can't just delegate a duty to a state and say, 'Okay, now it's your responsibility.' But that doesn't mean we shouldn't push ahead as fast as possible toward responsible delegation of program management. We should try to delegate responsibility to the level of government that is closest to the problem at hand, yet still able to handle all the administrative detail involved. Of course, this delegation must be done with strict and clearcut accountability, with ongoing EPA oversight to ensure that objectives are being met.

"The states need to understand what actions we consider timely and appropriate, both on their part and ours. There shouldn't be any surprises about when the feds will step in; how we will supervise their actions and how frequently.

"That's why information systems are so important. You can't delegate accountability to the states; you can only delegate responsibility. As Administrator of EPA, I can't go to Capitol Hill and deflect a question by saying, 'Well, I don't know because the state runs the program.' I and all my management colleagues here at EPA need a first-rate information system to stay informed of what is going on at other levels of government. And it must be an information system that is seen as relevant and valuable by workers in the field. Otherwise, they won't feed good hard data into it for use here in Washington."

Better Environmental Science: *We will work to expand the knowledge available to manage health and environmental risks. This priority involves improving the scientific basis for environmental protection decisions.*

"Better science and technology are crucial to our future success. Our risk assessments won't stand up to close scrutiny unless they are based on the very best science, and we won't be able to deliver on cleanup goals without top-notch technology.

"Environmental problems are solved not in offices, but in the field, and now—more than ever—we need improved technology to carry them forward. I've seen a struggle within EPA over the past few years concerning how to deal with Superfund cleanups. On the one hand, we have scientific information explaining what the problem is and what kind of an effort is needed to solve it. But matching that information up with the right technology is another story. Everybody wants to know: 'Where's the technology I need for that kind of solution.' I see this same pattern not just within Superfund, but across each of EPA's programs.

"We can't get better and quicker answers to these questions until we improve not just the scientific but the technical information at our disposal. And we need to look at the whole area of technology with an eye for new solutions. I'm strongly in favor of improving our in-house technological capability. But I'd also like to see us utilize knowledge that's outside the Agency.

"How can we do a better job of getting at this information? We need improved channels of communication with industry and with the academic community so we can be sure our scientific and technological information is state-of-the-art. We also need to spread federal grants around to the most promising researchers. By becoming creative partners in the world of research, we can hasten the day when we get exactly the knowledge and the tools we need."

Negotiation and Consultation: *In finding solutions to environmental problems, we will expand the use of negotiated regulations and consultative proceedings with a wide range of representatives from industry, environmental organizations, state and local government, and the general public.*

"We need to do a better job of involving a wide range of constituencies in the formulation of EPA policies and regulations. Industry and environmental groups obviously deserve to be consulted, but so do U.S. citizens and even the international community.

"The level of public involvement in EPA programs is changing. In the early 1970s, taxpayers gave overwhelming support to the new environmental programs pioneered by EPA. Polls today indicate that there is still overwhelming support for the general concept of environmental protection. But when EPA proposes specific measures these days, the public is a lot less inclined to accept the Agency line.

"Right now Americans are terrified about toxics. And, in a way, our own expertise is feeding this fear. We can detect and measure the most minute traces of toxics in the environment. But how do we prevent the public from getting scared to death when they learn of our findings?

"This situation is based, at least partly, on the tremendous fear of cancer that runs through our society. EPA says some pollutant causes cancer, and the public gets scared to death. We have to learn how to deal with these often irrational fears. And we can't do that unless we can get the essence of our risk-assessment reasoning across to millions of non-scientists.

"Another syndrome we're going to have to confront is: 'Not In My Backyard.' This is having a crippling impact on EPA efforts to safely manage waste. What are we going to do with waste from Superfund cleanups, where are we going to locate treatment facilities, if every neighborhood in the United States shouts 'Not in my backyard!'

"Another major challenge we face is that our problems and solutions are becoming more global in nature. There was a strong tendency in the past to focus almost all our resources and energies on domestic issues. Now we're dealing with all kinds of issues that transcend national boundaries: acid rain; stratospheric ozone; the greenhouse effect; the after-effects of disasters.

"EPA was heavily involved in dealing with the international aftermath of Chernobyl. All of us who were directly involved quickly learned just how small the world is, and how quickly our small planet can become contaminated.

"We're going to have to make the search for global solutions to global environmental problems a permanent part of our agenda. And we're going to have to start managing our domestic regulatory programs with the awareness that, directly or indirectly, they have global impact."

Enforcement: *We will enforce environmental laws vigorously, consistently, and equitably to achieve the greatest possible environmental results.*

"Sorting through enforcement responsibilities is a major aspect of environmental federalism. A large portion of our enforcement program is already being carried out by the states. State/federal enforcement agreements are trying to establish how this arrangement should work.

"Among the questions to be answered: How will the states and the feds go forward with an enforcement program together? Who will do what? And when? What will the feds do if the states don't take timely and appropriate action? Having answers to such questions is already changing the way we do business. Lately I'm beginning to hear people say: 'Hey, wait a minute, we did a pretty good job, but you didn't.' But even to reach this point has not been easy. It's been a challenge, and will remain a challenge.

"As we work through issues of consistency and equity in enforcement, we often find those are competing objectives. How can we be both consistent and fair when we're dealing with such different circumstances in each enforcement case? Well, it calls for a tremendous amount of judgment. That judgment must be exercised by managers at many different levels just within EPA, not to mention the states. Good communication among managers is and will remain vital."

Human Resources: *We will promote excellence and growth in EPA staff at all levels.*

"There has been a lot of talk about human resources in the past few years. And with good reason. Human resources can't be talked about too much. But action is needed, too, and we can't have that without an increasingly sophisticated human-resources program at EPA.

"EPA has one of the most important jobs there is to do in this country. But to do that job, we've got to have the best people. To get the best people and to keep them, we've got to give them every opportunity for growth and development, for input and feedback. Because if we don't do those things, we won't be able to carry out our mission the way the public expects us to, and the way we ourselves want to do."

Seven Themes, Uniform Consistency

"It's vital that we take a consistent approach in applying these seven management themes throughout EPA. We've got to have consistency.

"If we're going to talk about toxic A in the Pesticide Program, the RCRA Program, the Water Program, or the Air Program, we had better be talking about it in the same way. Consistency in risk assessment and in the way we manage each risk has got to be a major part of the way we manage EPA.

"We cannot accept a zero-risk approach, no matter how much idealists crave one. We are not living in a risk-free society, and there are technical and economic reasons why risk cannot be reduced beyond a certain point. But it is imperative that we deal with the issues before us in a rational way.

"That approach should be rational whether we are using it under Section 112 of the Clean Air Act, or to determine pesticide tolerances, or to make permitting decisions for hazardous waste sites. Striving for commonality in the way we assess and manage risks is a goal we must hold before us at all times.

"I'm hoping that even better ideas and even better management themes will emerge from our future work together." □

Underground Storage Tanks in the Spotlight

by June Taylor

You can't see them, but they number in the millions.

You can be driven out of your home or lose your water supply if one of them leaks near you.

They are underground storage tanks and have been called "ticking time bombs." They represent one of the most widespread threats to our ground-water resources, from which over half of our country gets its drinking water.

Originally placed underground as a fire safety practice, these tanks become a hidden source of pollution when they and connected pipes corrode and develop holes, or for other reasons break. Leaks and resulting fumes can also cause fires and explosions when the unseen products accumulate in basements and storm and sewer pipes.

The number of leaking tanks reported has increased dramatically. A generation of bare steel tanks installed in the late 1950s and early 1960s are now corroded, leaky hulks. Many of these old tanks are "orphans"—their owners are out of business, victims of a rapidly changing oil market. The next time you see an abandoned gas station, you might wonder if the owner properly emptied and closed out the tanks, or if there is leftover fuel just waiting to leak out.

On April 17, 1987, the Environmental Protection Agency published proposed regulations for dealing with the estimated two million commercial underground tanks that store petroleum products (gasoline, diesel, jet fuels) and hazardous chemicals. These proposals are called for under Subtitle I amendments to the Resource Conservation and Recovery Act (RCRA). Heating oil, small residential, and farm tanks are currently exempt from federal law.

EPA is proposing that all tanks must be protected against corrosion and must have leak-detection devices. New tanks must meet these requirements at the time of installation, which will add about 10 percent to the cost of a new tank and its connected piping. The EPA proposals also call for national standards for new tanks to ensure that tanks in the future will be better built and less likely to leak, and that if they do leak the owner or operator will be alerted to the problem by leak-detection devices. A number of leak-detection methods are allowed under EPA's proposal.

EPA's Office of Research and Development (ORD) has been investigating the effectiveness of various leak-detection devices at two EPA laboratories. At Edison, New Jersey, ORD has installed two tanks in controlled, lined excavations and is evaluating devices placed inside the tanks to test their tightness. At its Las Vegas lab, ORD is evaluating systems that detect leaks in the soil or water outside tanks. While its research teams are evaluating the types of devices already available to tank owners, EPA hopes that new, improved devices will be developed for this potentially enormous and lucrative market.

Under the proposed regulations, owners putting new tanks into the ground must certify that the tank is properly installed. Poor installation has been a major cause of leaks, as evidenced by the experience of Farmington, NM. In 1986, that city decided to put two of its above-ground tanks underground. Unfortunately, the contractor who did the work forgot to put plugs in the tanks' washout holes. As soon as the tanks were filled they leaked thousands of gallons of gasoline. The city thought the gas had been stolen and installed a fence around the tanks and put locks on them. Then they filled them up again! More than 20,000 gallons of fuel were lost, and the city barely stopped the contamination from reaching the water supply. Several hundred thousand dollars have already been spent on cleanup, and the work continues.

The regulations also deal with tanks already in the ground. Surprisingly, only about half of these are for retail gasoline sales. The remainder are generally owned by small plumbing, electrical, and contracting firms, and other types of business that have four or more trucks and fuel them up from their own pumps.

Recognizing the problems of small business, EPA would allow owners of existing tanks three to five years to install leak detection devices, which can be retrofitted onto existing tanks, or to test their tanks for leaks. Then, over the next 10 years, under the EPA proposal, all tank systems would have to be upgraded to meet the new standards (by retrofitting corrosion and leak detection), or be replaced with brand new systems. The goal is that at the end of the 10-year period all tanks will be safer and equipped to prevent pollution.

The EPA proposals also contain special requirements for piping, a major source of leaks, and devices to prevent overfill spills. They address proper tank repair and closure, and other tank management practices, and require that records must be kept to show correct steps were taken. New chemical tanks must have a second wall around the tank, or have a lining or some other barrier in the pit to contain any leaks.

The proposals require that leaks be reported to the closest "regulating agency," which could be a local fire department or a local or state health or environmental agency. In the absence of acceptable local or state programs, the job will be done by EPA, which will be responsible for seeing that the contaminated area is cleaned up.

However, EPA feels that local or state officials will usually be in the best position to decide how much cleaning up should be done. The level of cleanup required after a leak is detected will be based on whether the threatened ground water is used for drinking or industrial or other purposes. Thousands of cleanups will probably be necessary, and the proposed regulations reflect the Agency view that getting the cleanups underway is more important than delaying for arguments about the need for a strict national standard that may not be technically achievable.

Who bears the cleanup costs, which can range from several thousand dollars—if the leak is caught quickly and doesn't reach the water table—to hundreds of thousands or even millions if long-term groundwater cleanup is needed? Congress specifically required that petroleum tank marketers carry a minimum of one million dollars in insurance or other "financial responsibility" coverage to pay for cleanups and any other damages. Congress also created the Leaking Underground Storage Tank (LUST) Trust Fund to help pay for cleanups of petroleum leaks from orphan sites, where the source of the leak is in doubt or where the owner is insolvent.

Almost every community in the United States has underground storage tanks—and often lots of them. The new tank proposals affect one of the largest "regulated communities" under EPA's jurisdiction.

The Agency has been working with numerous trade associations to let tank owners know what's coming down the pipe. While the response has generally been that EPA's proposed program is reasonable, there is some fear that many marginal businesses, primarily small gasoline stations, may suffer severe financial hardship if forced to comply, and environmentalists think the proposals are too lenient.

Ron Brand, Director of EPA's Office of Underground Storage Tanks, believes that tank owners and operators must be able to carry out the new requirements. Says Brand, "Anything we propose has to be realistic. The leak detection and other requirements have to be something a gas station owner or the high-school kid who's running the gas station while the boss is out can handle." Brand is concerned that states develop acceptable programs to carry out federal law in lieu of EPA. Many states already have active programs, some stricter than the EPA proposals, but many do not.

Brand notes, "Before there was a federal law, there were leaks, and somebody dealt with those that were reported. Maybe it was the fire marshal, maybe the health department, but *somebody* responded. We want them to continue to respond and we hope our regulations will make their jobs easier by ensuring that future tanks are better built and better installed, and that leaks are caught before they cause a catastrophe. We also have the capability to do research (such as developing cleanup techniques and testing leak-detection devices), to develop training programs, and to produce other information that will help states and local governments, as well as tank owners and operators. That's a better role for EPA than trying to inspect every tank in America."

For more information on the proposed regulations, write to the Office of Underground Storage Tanks (WH 562A), EPA, 401 M St., SW, Washington, D.C. 20460 or call the RCRA Hotline at 800/424-9346 (in the Washington, D.C. area, 382-3000). Final regulations are expected to be issued early in 1988. □

(Taylor is a communications consultant to EPA's Office of Underground Storage Tanks.)

EPA Specialists Help Solve a Mystery in Cameroon

by Harry Compton and Alan Humphrey

Lake Nyos, a volcanic crater lake in the Republic of Cameroon in Africa, showing the spillway through which carbon dioxide escaped after the gas rose to the surface of the lake in a cloud formation.

More than 30 volcanic crater lakes form a chain through the Republic of Cameroon's northwestern bush country near the Nigerian border. Local legend holds that the lakes are inhabited by spirits—some good, some bad. Lake Nyos was believed to house a benevolent spirit until August 21, 1986. But that night, a mysterious cloud rose out of the lake and surged over the northwest rim of the crater into the adjacent low-lying territory. In a matter of hours, 1,700 people, 3,000 cattle, and untold numbers of wildlife were dead.

The location of the calamity is a remote highland region featuring some of Africa's most spectacular scenery. It is a territory of far-flung cattle ranches and agricultural settlements nestled among volcanic hillsides. The populace is primarily the Fulani and Bamileke tribes, who are further subdivided by religion (Catholicism, Islam, and folk religion) and language (French, English, and 28 other local dialects). Here the roads are little more than widened paths and telephone communication is nonexistent outside of the provincial center of Bamenda, a rough four-hour ride from Nyos.

Sadly, the very isolation that has left this area untouched also hampered word of the disaster. It took two days for the full story to reach the capital city of Yaounde. Once the situation became known, however, international support was immediate, with half a dozen countries joining forces to provide medical aid and scientific expertise. The U.S. team, for example, included not only medical specialists, but also chemists, a vulcanologist, a limnologist, and ourselves—environmental scientists from EPA's Environmental Response Team.

First in was a medical team from the Armed Forces Institute of Pathology. Second came a group of chemists and vulcanologists headed by Dr. John Lockwood of the Hawaiian Volcano Observatory. Finally, little more than a week after the killer cloud had struck, we, too, were on our way to Cameroon, along with George W. Kling, a limnologist from Duke University. Our job was to help figure out what had happened and why. In that way, we might be able to prevent it from happening again.

Our first problem was the rainy season. Rescue and supply efforts naturally took first priority, but the rain was causing great delays for the limited number of Cameroonian aircraft. Furthermore, the unpaved roads of the Nyos region had become oceans of mud traversable only by large, four-wheel-drive vehicles operated by experienced drivers. Because of these transportation limitations, we had to scale down our equipment to items that could be backpacked, hung on a utility belt, or hand-carried to the provincial city of Bamenda, where other U.S. team members were already at work.

In Bamenda, we were briefed by Dr. Edward Koenigsberg, who was coordinating U.S. disaster assistance. Initial findings from survivors seemed to indicate that conditions differed according to proximity to Lake Nyos (casualties and health effects were reported as far away as 12 kilometers from the lake). A herdsman on a ridge above the lake reported seeing lights flashing on the lakes's surface and hearing approximately 20 seconds of deep rumbling. Those near the crater also heard rumblings. Yet survivors from areas more distant from Lake Nyos said they smelled an overpowering odor, alternately described as rotten eggs or gunpowder, usually an indication of sulfur. Initially, skin lesions on both the living and the dead from these regions seemed to support the theory that a sulfur species had leached out of the cloud at some distance from the lake. However, sampling and analysis by members of the U.S. team found no evidence of sulfur compounds. And except for the herdsman nearest the site, no one had seen anything.

Koenigsberg also told us about the strange report from Subum village, located 10 kilometers from Lake Nyos. Almost all the inhabitants had been killed or significantly affected by the gas cloud. The only survivors were the women and infants confined to the second-floor maternity ward of the Subum dispensary, the only two-story structure in the village. This would later prove to be a significant clue to explain the Nyos incident.

After meeting with Dr. Koenigsberg, we flew to the town of Wum, the largest community near Nyos, and the site of a refugee camp. From Wum, we were helicoptered to Lake Nyos to link up with Dr. Lockwood's team. Circling the lake, we were struck by the size of it: over a mile in length, perched among the mountaintops with sheer cliffs on both sides. At the north end, a majestic waterfall dropped over 75 feet to a lush valley below. Floating mats of vegetation, uprooted on the lake's shore by the tremendous volume of displaced water, were visible everywhere.

We looked out over this now-calm, idyllic lake and tried to comprehend what had taken place here only days before. Lockwood told us they had been hampered by foul weather and transportation problems. Furthermore, French investigators first at the site believed there would be further disturbances and had warned others to stay off the lake. But we were eager to get out on the lake; no samples had been taken and the weather was good. Assisted by chemist William Evans, we collected gas, water, and biological samples at different levels of the 220-meter deep lake.

Upon returning to shore, however, we learned that air transport back to Wum was not available. A truck could pick us up, but we would have to meet it in Nyos village at the foot of the northwestern slope, an hour's hike down densely vegetated mountainside. Nyos village had been wiped out by the gas. Entering the village at sunset, we saw an African village like an old Tarzan movie, but with brick and mortar houses totally empty. There were no villagers' bodies, but their mass graves were visible. Lifeless, decomposing cattle littered the area without a worm or fly on them, because even the insects had been killed by the gas. Even the vultures wouldn't land. They just circled endlessly. The stench and the silence were overpowering evidence that the Grim Reaper had passed through.

The following day, we returned to the lake for further sampling and a complete physical survey. Air samples were taken at the outfall of the lake, as well as further analysis of the gaseous bottom waters. We had to sample quickly, however, to avoid being caught on the lake by the daily monsoons which blew up suddenly. All samples were brought back to Wum that evening for testing.

The result of all this testing was a relatively simple theory to explain the Lake Nyos incident. U.S. investigations suggested that carbon dioxide had apparently been seeping from deep magmatic sources into the lake bottom for some time. Extreme pressure caused by the lake's depth resulted in a massive build-up of dissolved carbon dioxide. Something caused this deadly gas to come out of solution and literally be belched up to the lake's surface. Evidence of the force of this action was seen on a cliff at the southeastern corner of the lake, where we measured a high water mark left by a wave of 80 meters.

Four conditions might have caused this to occur: (1) a fast temperature differential causing a lake overturn which displaced the gas; (2) de-stabilization caused by some of the violent storms of that particular rainy season; (3) reduced low-level pressure causing a sudden loss of solubility; or (4) a rock-
evidence that such a slide had taken place, we were unsure whether it had happened before the gaseous emission or because of it.

Whatever the initial cause, the gas rose to the surface and was carried by prevailing winds over the northwestern rim of Lake Nyos. Carbon dioxide, being twice as heavy as air, seeks the lowest possible level; hence, it followed creek gullies and river beds. Tragically, many villages lie along these waterways. The incident took place at 9:30 p.m , when most inhabitants had eaten and were preparing for bed.

The cloud probably overcame and asphyxiated many of the victims as they slept; certainly the forensic findings saw little or no sign of agonized struggle or suffering. Even those who were awake could not escape because carbon dioxide is colorless and odorless. Nor does exposure to high concentrations cause traumatic warning signs. The lesions first attributed to sulfur compounds actually resulted from bodies lying in fixed positions for up to 36 hours.

The story of the Subum dispensary survivors also led us to conclude that the cloud reached a height of approximately 10 feet from the lowest ground level in any given area, a theory supported by the survival of herdspeople in close proximity but at a higher altitude than the lake.

The U.S. investigators initially recommended a much more extensive study during the dry season, when data would be easier to collect and rescue efforts would be over, making transportation more available and feasible. But the commitment of the United States government to Cameroon pointed to a more immediate investigation. A similar incident resulting in 37 deaths had taken place at the region's Lake Manoun in 1984. Further, the local people had an oral history that seemed to identify similar incidents in the past, although these were tightly bound to legend and tribal religion.

The decision was made to examine another half dozen lakes in the Nyos region. This team included Dr. Lockwood, William Evans, George Kling, and ourselves. We conducted air reconnaissance and lake sampling from September 9 through 11, with negative findings about any further immediate dangers.

Despite the pressures of sampling work, we did get a chance to visit the Wum refugee camp, where the children were fascinated by our different skin color. They rubbed our hands and arms, pointing and repeating a remark translated as "white men!" Authorities explained that in this part of Cameroon, many people go through their whole lives without seeing Caucasians. Luckily, among the items we hadn't left behind was an oversized bag of hard candy. Needless to say, Americans were very popular among these rural Cameroon children.

A year later, most of the world has forgotten about the "killer lake" in Cameroon. Disasters and catastrophes seem to replace themselves with disturbing regularity. But for us, Lake Nyos is a living, breathing entity, not unlike the spirit the Cameroonians believe lives there. But now we have an amulet to protect against the beast: a degassing system developed by Robert Cobiella of EPA Region 2.

An air lift pump designed to suit the economic and power limitations of a Third World nation, it consists of a drop pipe which delivers compressed air below the water's surface. The resulting mixture of air and water will be lighter than the surrounding water/gas solution, causing the gas to rise slowly to the surface over a longer period of time. This should diffuse the deadly carbon dioxide build-up that decimated the Nyos region.

From now on, the spirit of Lake Nyos should remain at peace. □

(Compton is an environmental engineer with EPA's Environmental Response Branch in Edison, NJ, and Humphrey is an environmental scientist with the same branch.)

Update

A review of recent major EPA activities and developments in the pollution control program areas

AIR

Lead Standard Violations

EPA has announced that it is seeking about $4.7 million in penalties from four refining companies for violations of the lead phase-down regulations.

Among companies cited in the violation notices is Citgo Petroleum Corp., of Tulsa, OK, which the Agency alleges improperly reported importing almost 23 million gallons of leaded gasoline containing less lead than Agency standards allow. In fact, the imported product was unfinished gasoline blend stock. The Agency said that by labeling it as finished gasoline, Citgo improperly claimed over 15 million grams of lead rights which it could sell, trade, or use in the future under the Agency's lead banking program.

In additon to Citgo, the violation notices were issued to Aectra Refining and Marketing, Inc., and Coastal Refining and Marketing, Inc., of Houston, TX; and Canal Refining Co. of Church Point, LA.

Clean Air Standards

EPA announced major revisions of the national clean air standards for particulate matter, changing the focus from larger, total particles to smaller, inhalable particles that are more damaging to human health.

The new rules replace the current standards for total suspended particulate matter (TSP) with a new indicator that includes only those particles that are 10 micrometers or smaller. These smaller particles are likely to be responsible for most of the adverse health effects.

Particulate-matter air pollutants are largely dust, dirt, soot, smoke, and liquid droplets directly emitted into the air by sources such as factories, power plants, cars, construction activity, fires, and natural windblown dust.

HAZARDOUS WASTE

Violation of Hazardous Waste Laws

EPA and the State of Louisiana have asked a federal court in Baton Rouge, LA, to impose penalties against Browning-Ferris Industries' subsidiaries, Browning-Ferris Industries, Chemical Services Inc. (BFI-CSI), and CECOS International, Inc., for violations of federal and state hazardous-waste laws at an active commercial hazardous-waste facility in Livingston, LA. They are asking for penalties up to $25,000 per violation per day.

The government's investigators have detected over 2,800 Resource Conservation and Recovery Act (RCRA) violations over the six years of BFI/CECOS operations that have been evaluated.

EPA Administrator Lee M. Thomas said, "This is a particularly important case because of the large number of violations of federal and state laws found...." "The substantial penalties we are seeking reflect EPA's strong commitment to enforcing the law to protect human health and the environment."

BFI-CSI owned and operated the facility from 1978 to 1983. CECOS, which now handles all of BFI's hazardous-waste operations, acquired ownership and operation from BFI-CSI in 1983. BFI is one of the nation's largest waste handlers.

TOXICS

Asbestos Abatement Loans and Grants

The Agency has offered $8 million in financial assistance to public and private schools in the second round of funding for asbestos-abatement projects under the Asbestos School Hazard Abatement Act of 1984 (ASHAA).

In this round of funding, the Agency offered awards to 35 school districts that applied for federal funds for 66 separate projects.

EPA based school selection upon the severity of the school's asbestos-related problem and its financial need. Earlier this spring, EPA awarded $34.2 million in financial assistance, for a total of over $42 million in federal grants and loans offered in 1987 to needy schools to help abate asbestos hazards.

Reporting Form Proposed

EPA has proposed a toxic-chemical release form which owners and operators of facilities using certain chemicals will be required to submit annually to the Agency and to the states.

The reporting requirement applies to owners and operators of manufacturing facilities that have manufactured, processed, or otherwise used a toxic chemical listed on the emissions-inventory list in excess of a specified quantity.

EPA Administrator Lee M. Thomas said that, "By July 1988, thousands of facilities in the United States will be required to report environmental releases of over 300 toxic chemicals annually to EPA and the states. For the first time, this information will be made available to the public and will allow for more informed participation by the public on toxic issues."

Appointment

Renate Kimbrough

Renate Kimbrough has been named to the new post of Regional Director for Health and Risk Capability. She will advise the regional offices on risk reduction and management.

Dr. Kimbrough began her career at EPA in 1970 as a research medical officer and from 1972 to 1973 served as Director of the Toxicology Laboratory. Since 1974, she has served as a Medical Officer with the U.S. Public Health Service, Center for Environmental Health, Centers for Disease Control.

Dr. Kimbrough earned her medical degree from Gottingen University in West Germany. She is a member of a number of organizations, including the Society of Toxicology and the American Academy of Pediatrics. She is also a Diplomate of the American Board of Toxicology.

Summertime. Photo by Steve Delaney, EPA.