

From Source Water to Drinking Water: Workshop Summary

Lawrence Reiter, Henry Falk, Charles Groat, and Christine M. Coussens, Editors, Roundtable on Environmental Health Sciences, Research, and Medicine

ISBN: 0-309-54547-1, 126 pages, 6 x 9, (2004)

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FROM SOURCE WATER TO DRINKING WATER

Workshop Summary

Lawrence Reiter, Henry Falk, Charles Groat,
and Christine M. Coussens, *Editors*

Roundtable on Environmental Health Sciences, Research,
and Medicine

Board on Health Sciences Policy

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THE NATIONAL ACADEMIES PRESS
Washington, D.C.
www.nap.edu

THE NATIONAL ACADEMIES PRESS 500 Fifth Street, N.W. Washington, DC 20001

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This study was supported by the contracts between the National Academy of Sciences and the National Institute of Environmental Health Sciences, National Institute of Health (Contract No. 282-99-0045, TO#5); National Center for Environmental Health and Agency for Toxic Substances and Disease Registry, Centers for Disease Control and Prevention (Contract No. 200-2000-00629, TO#7); National Institute for Occupational Safety and Health, Centers for Disease Control and Prevention (Contract No. 0000166930); National Health and Environment Effects Research Laboratory and National Center for Environmental Research, Environmental Protection Agency (Contract No. 282-99-0045 TO#5); American Chemistry Council; and Exxon-Mobil Corporation (unnumbered grants). Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the organizations or agencies that provided support for this project.

This summary is based on the proceedings of a workshop that was sponsored by the Roundtable on Environmental Health Sciences, Research, and Medicine. It is prepared in the form of a workshop summary by and in the names of the editors, with the assistance of staff and consultants, as an individually authored document.

International Standard Book Number: 0-309-09306-6 (Pbk)
International Standard Book Number: 0-309-54547-1 (PDF)

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*“Knowing is not enough; we must apply.
Willing is not enough; we must do.”*
—Goethe



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Although the reviewers listed above have provided many constructive comments and suggestions, they were not asked to endorse the final draft of the report before its release. The review of this report was overseen by **Melvin Worth**, Scholar-in-Residence, Institute of Medicine, who was responsible for making certain that an independent examination

of this report was carried out in accordance with institutional procedures and that all review comments were carefully considered. Responsibility for the final content of this report rests entirely with the authoring committee and the institution.

Preface

The Institute of Medicine's Roundtable on Environmental Health Sciences, Research, and Medicine was established in 1988 as a mechanism for bringing the various stakeholders together to discuss environmental health issues in a neutral setting. The members of the Roundtable on Environmental Health Sciences, Research, and Medicine come from academia, industry, and government. Their perspectives range widely and represent the diverse viewpoints of researchers, federal officials, and consumers. They meet, discuss environmental health issues that are of mutual interest (though sometimes very sensitive), and bring others together to discuss these issues as well. For example, they regularly convene workshops to help facilitate discussion of a particular topic. The Roundtable's fifth national workshop entitled *From Source Water to Drinking Water: Ongoing and Emerging Challenges for Public Health* continued the theme established by previous Roundtable workshops, looking at rebuilding the unity of health and the environment. This workshop summary captures the discussions and presentations by the speakers and participants, who identified the areas in which additional research was needed, the processes by which changes could occur, and the gaps in our knowledge. The views expressed here do not necessarily reflect the views of the Institute of Medicine, the Roundtable, or its sponsors.

This workshop brings back many memories of the early 1970s, which was a critical time for environmental issues. It was when people from all walks of life began to acknowledge the strong linkage between the environment and health. Bipartisan support resulted in significant actions on Capitol Hill with the passage of the Clean Air Act, the Safe Drinking Water Act (SDWA), and the Clean Water Act (CWA)—bills that laid the foundation for protecting health from environmental threats.

Even though they have since been modified a little, the basic tenets of these acts still prevail and are helping us even today to try to keep our air and waters clean and to make our drinking water safe.

This workshop provided an opportunity to look at the progress since the Safe Drinking Water Act and the Clean Water Act. It looked at previous and future challenges that will continue for those of us in environmental health. Many people realize that providing ample and safe drinking water is growing in complexity as policy makers are under pressure to balance the needs of numerous stakeholders. There is pressure on this basic resource because of industrial growth as well as agricultural, housing, and recreational needs. Rather than seeing an easement of water needs, the pressures will continue for the foreseeable future.

Too often, we rely on historical precedent for providing basic services to our population, this includes providing safe drinking water. Since the late 1800s, we in the United States have believed that all we had to do was locate our cities next to a large river from which we could bring in clean drinking water at one end and dispose of wastes at the other. Alternatively, we have relied on groundwater as a water source and continued to dispose our wastes in rivers, lakes, and streams. Throughout the workshop, we heard from many participants that these no longer are viable solutions since we are already tapping into every major water aquifer in the United States. Clearly this reinforces the adage that your waste water is someone else's drinking water.

The problems in ensuring safe water go hand in hand with urbanizing. In the United States, at the beginning of the last century, systems for providing safe drinking water began to be overtaxed, and we increasingly were required to treat the water that comes in (through chlorination, filtration, etc.) and to treat the wastewater (via the public owned treatment works [POTWs] primary, secondary, and now tertiary treatment required in many communities). Despite all these efforts, we still have problems such as the following:

- Treatment leaves chemical residues in our drinking water.
- Our infrastructure for the treatment and delivery of drinking water does not always work to keep drinking water safe, and we have outbreaks of drinking water-borne disease. This is further problematic for the vulnerable populations (infants; the elderly; the immunosuppressed via congenital immunodeficiency, transplants, HIV, and/or cancer therapy) who may be susceptible to lower levels of pathogens; drinking water from the tap must be safe for everyone.

- We have polluted some of our source waters by allowing polluting activities in sensitive groundwater areas and tolerating contamination of surface water, via wastes from combined sewer overflows, POTWs, and agricultural runoff (“nonpoint sources”).

This does not imply that our drinking water is unsafe, but that priorities need to be established to determine which chemicals or pathogens should be regulated. Workshop participants noted that not everything that can be monitored should be monitored and that science needs to continue to underlie the regulatory decisions. The contaminants selected for regulation should be based on the results of scientific research performed and supported by research at the Environmental Protection Agency, National Institute of Environmental Health Sciences, National Center for Environmental Health, and many academic institutions. The regulations of the contaminants would be based on their actual human health implications and ramification and on the best practices of the scientific research and discovery.

At the same time, it is clear that not all of the goals of the SDWA and CWA have been fulfilled. We need to stick to the original vision of safe drinking water for all Americans and elimination of polluting discharges to water. It is ironic that permits under the National Pollutant Discharge Elimination System allow potential low levels of polluting discharges rather than eliminating them. We need to rethink our strategy both for provision of safe drinking water and for disposal of human waste materials. Some strategies were suggested at the workshop:

- Reuse is a reality. Everyone living downstream is using water that has previously been used many times. If we can provide safe drinking water via reuse in a spaceship we can do this for cities too. We must do so with strict standards with respect to pathogens and chemical residues.
- Much of our municipal water is used for irrigation, not drinking. We treat all water as if it will be used for consumption by humans, which may not be cost-effective. Communities have begun to experiment with the feasibility of alternative systems for delivering drinking water versus irrigation water. Such innovative approaches need to be researched but they need careful evaluation.
- The state and federal governments must continue to collaborate on assessing drinking water quality and source contamination on a regional basis.

- Source protection for groundwater is a priority and local communities should continue to be empowered on a regional basis with tools for assessment as well as for management (offer across multiple political jurisdictions).

Clearly, source protection for surface water urgently needs broad regional, state, and national attention. The assessment function (above) is critical but it is also critical to develop tools and incentives for management on a broad scale. Ultimately, it is time for Congress to consider the best way to bring the goals of the CWA and the SDWA together in order to ensure protection of the public's health and to keep pace with the true water demand for people, while protecting the environment. The next reauthorization of the SDWA should be coordinated with the reauthorization of the CWA while meeting the needs of the natural environment, industry, and farmers to ensure that communities have the tools that they need to continue to provide safe drinking water. Such a reauthorization process should establish formal mechanisms for involvement of the CDC/ATSDR to bring the best public health science. The NAS could play a role via committee that could review the science underlying these acts and advise Congress on the research, the information tools, the management tools, and the engineering alternatives that need to be pursued to provide safe drinking water to people in the future.

Paul G. Rogers, Chair
Lynn Goldman, Vice-Chair

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Summary

The reliable provision of safe drinking water in the United States and other countries represents one of the outstanding public health accomplishments of the past century. This capability derived from major and mutually reinforcing efforts by researchers in public health, engineers, and governments at all levels—municipal, state, and federal—to put the necessary infrastructure in place, develop standards and regulations, and implement them effectively. As a result, the majority of people in the United States today enjoy an unprecedented level of protection and safety in the drinking water they consume. However, the system that was put in place for delivering safe and adequate supplies of drinking water has been in existence for more than 100 years. During the ensuing century, the United States has experienced a surge in population growth, which is projected to increase until 2050; a shift of population from densely populated urban areas to sparsely populated rural areas; and greater demands on water for multiple needs such as recreation, drinking water consumption, industrial use, and agricultural use. All of these needs have resulted in additional pressure on our waterways and will likely affect our ability to supply adequate water in the future, according to some workshop participants. This workshop, which was sponsored by the Institute of Medicine's Roundtable on Environmental Health Sciences, Research, and Medicine, provided an opportunity to look at the progress achieved since the passage of the Safe Drinking Water Act and the Clean Water Act. It looked at previous and future challenges that will continue in environmental health.

CURRENT STATUS OF SCIENCE AND POLICIES FOR ENSURING THE PROTECTION OF SOURCE AND DRINKING WATER

To answer the question of whether science and technology are adequately providing safe drinking water we should first understand the risks that drinking water may carry, noted Jeffrey Griffiths, Tufts University School of Medicine. Some of them are related to the population, which is not only growing in size but changing in its characteristics—particularly with respect to enhanced sensitivity to waterborne contaminants. Thus, at the same time that water must be reused—given the growing demand—there is additional pressure to ensure that the drinking water remain at levels of acceptable public health protection. Meanwhile, the changing activities and increasingly concentrated locations both of people and of industries result in significant levels of new emerging contaminants. These, together with agents already well established in the inventory, confront us with approximately three million potential chemical contaminants—that calls for paradigm shifts in the ways we think about these issues, suggested Griffiths.

There are many interfaces between the science and the policy of the Safe Drinking Water Act (SDWA), according to Frederick Pontius, president of Pontius Water Consultants, Inc. In fact, the policy and current provisions of the SDWA grew out of our prior failures and scientific advances. There are the legal mandates and requirements that control options, exposures, dose–response relationships, costs and benefits, laboratory methods, and agency processes. The SDWA is a mixture of different lines of reasoning, different facts, different assumptions, and different judgments made by people with different perspectives. Such decision making cannot be based on science alone and requires a blending of science and policy in order to achieve the necessary end points, noted Pontius. Scientists are struggling with data gaps across all aspects of regulation from how to select contaminants to the establishment of health goals. Further challenges for maintaining the use of the best science include filling data gaps and ensuring high-quality peer reviews so that future and revised drinking water regulations are based on the best available science.

ASSESSMENT AND MANAGEMENT PRACTICES: IMPACT ON HEALTH

Source water protection needs broad regional, state, and national attention to continue to ensure the availability of safe drinking water. But it also must be recognized that local planning and community involvement are the cornerstones for approaching source water protection in a holistic plan, according to Douglas “Dusty” Hall of Ohio’s Miami Conservancy District. Many localities have developed comprehensive programs to balance the need for source water for public drinking and the use of rivers and aquifers for industrial purposes. While this has helped to ensure the availability of safe drinking water, many urban areas are experiencing population loss to rural townships, which do not have comprehensive planning and rely heavily on household sewage treatment systems, which have an estimated failure rate of 25 percent, and only a small fraction (8 percent) are subject to oversight in Ohio. Hall suggested that partnerships are needed to help stakeholders understand the health effects of increased population growth in areas with limited authority to implement comprehensive planning.

Current Environmental Protection Agency (EPA) estimates suggest that approximately one-third of all assessed rivers, streams, and lakes are impaired, primarily through nonpoint source pollution, noted Thomas Christensen of the U.S. Department of Agriculture’s Natural Resources Conservation Service. Although these pollutants come from many sources, agricultural practices are a significant contributor, especially in the Mississippi River basin. Agricultural pollutants, such as sediment, nutrients, pesticides, and pathogens, contribute to the cost of providing safe drinking water.

Of the potential nutrients, nitrogen and phosphorus are two nutrients of concern because of their potential health linkages, noted Kenneth Reckhow of Duke University and the University of North Carolina. Although scientists have broad understanding of their sources, both natural and anthropogenic scientific information available in current models do not provide the necessary reliability for making water quality decisions. He suggested that scientists will have to employ adaptive management to improve their models by observing how the actual water body responds, and then use this information to augment the predictive power of the model system.

To begin to address the assessment, the Safe Drinking Water Act requires the states to identify areas that provide drinking water, delineate

their boundaries, register potential sources, assess their vulnerability to potential contamination, inform the public of the results, and implement a source water protection program, noted Greg Rogers of the Texas Commission on Environmental Quality. This can be a challenge for many states, including Texas, which has more than 6,000 separate water systems, approximately 20,000 public water supply wells, and 600 water intakes. By partnering with federal agencies, the commission was able to develop a database that can address water needs from the state level and aid in planning new water intakes and monitoring for contaminants through modeling and data collection.

EMERGING ISSUES IN PROVIDING SAFE DRINKING WATER

Chemical and biological pollutants, whether from natural or human sources, that are regulated under various state, national, and international programs represent but a small fraction of the universe of chemicals present in the environment. The majority of contaminants are not regulated; however, this does not imply that they do not pose risks, according to some participants. Some contaminants are now being recognized as emerging pollutants, but it is important to realize that the vast majority of recently identified potential pollutants were previously unrecognized and are of interest now as a result of advances in chemical analysis, noted Christian Daughton of the U.S. Environmental Protection Agency. Some of these chemicals are consumer goods and pharmaceutical agents that we have routinely neglected, ignored, or omitted. In addition, scientists are just beginning to evaluate what defines persistence because even chemicals that have short environmental half-lives can be persistent if they are continually reintroduced to water.

An emerging area for studying the source of contamination is the hydrologic cycle, which connects surface water, groundwater, and the atmosphere (atmospheric deposition), according to Mark Nilles of the U.S. Geological Survey. Whereas ammonia emissions are correlated with agricultural areas, nitrogen oxides are strongly associated with industrial activities. The highest concentration of nitrogen oxides is near areas of significant industrial activity and fossil fuel combustion. Mercury deposition, however, is more complex and not associated with agricultural or industrial practices; it is concentrated predominately in the Indiana-Minnesota-Wisconsin corridor and in the southeastern United States.

Science has not made as much progress in the past decade as needed to address emerging waterborne pathogens, noted Joan Rose of Michigan State University. Although industrialized countries have made significant progress in containing and eliminating outbreaks as a result of infectious agents, only 1 percent of the organisms associated with disease have been identified that might be found in wastewater. This has dire consequences because new pathogens are identified every year and researchers are learning of the role of infectious agents in chronic diseases such as ulcers and cancer.

GLOBAL WATER ISSUES: IMPLICATIONS AT THE WATER–HUMAN HEALTH INTERFACE

Central to the rising demand for water is the increase in population growth that is projected to continue until 2050 and beyond. The per capita availability of water across the planet is decreasing because the population is increasing, while the total amount of water is static. Approximately 1.1 billion people do not have access to clean drinking water and 2.4 billion do not have access to adequate sanitation services, noted Peter Gleick of the Pacific Institute for Studies in Development, Environment, and Security. These failures to meet basic human needs for water lead to millions of outbreaks each year of water-related disease such as cholera, dysentery, schistosomiasis, and guinea worm.

Just as governments have struggled to meet basic human needs for water, they have similarly struggled to meet environmental needs for water, noted Gleick. The twentieth century was a time in which water demand was met through increased water supply. Dams, aqueducts, reservoirs, and pipelines were constructed without an understanding of the ecological implications. The result has been ecosystem collapse and contamination because of modified river flows, fluctuating temperatures, decreased water quality, and dams that trap sediments needed to maintain river deltas. Thus, Gleick called for governments and organizations to adopt a new paradigm for managing water and policy. Governments have failed to realize that programs that work in the developed world may not be the best systems to address these basic needs in developing countries. There are many connections between water policy and human health, and they are complex. This requires that our approaches to addressing them also be complex—our systems have to be multiple and varied.

CHARTING A COURSE FOR THE FUTURE

There has been much progress since the passage of the Safe Drinking Water Act and the Clean Water Act. Regulations adopted under these regulations served as a means of enacting many beneficial measures; however the issues facing society today are more complex, often having societal and personal implications, and are not fixed by quick regulatory decision. Workshop participants discussed whether the approaches that government has traditionally used are feasible as the United States faces a growing population and increased consumption per capita. Further, any new paradigm will not be the sole regulatory domain of one agency, but will rather rely on smaller shifts and increased coordination among multiple agencies at the federal, state, and local levels.

The participants noted that water has to be valued as a commodity and that wastewater treatment is costly, especially with regard to reclaiming water for beneficial purposes. In most states, the entire burden of water quality is placed on the drinking water system, and its customers to pay for what happens upstream. Planned potable reuse also affects private wells as people move from urban to suburban areas. A small, but malfunctioning septic tank system can have the same microbiological loading in certain locations as a large metropolitan area wastewater treatment plant.

Participants suggested that government has to achieve water capture at the community and watershed levels for purposes such as recharging groundwater. This could work in concert with land-use planning and monitoring, because the ability to understand the effects of point and nonpoint source pollution has to be addressed on a local level.

Remarks and Charge to Participants

*Michael Shapiro**

Although frequently taken for granted, the reliable provision of safe drinking water in the United States and other developed countries represents one of the outstanding public health accomplishments of the past century. This capability derived from major and mutually reinforcing efforts by researchers in public health, by engineers, and by governments at all levels—municipal, state, and federal—to put the necessary infrastructure in place, develop standards and regulations, and implement them effectively. As a result, the vast majority of people in the United States today enjoy an unprecedented level of protection and safety in the drinking water they consume.

This is not to say the job is done, because as we look back on significant accomplishments—as well as take pride in a level of protection that continues to improve over time—we recognize that a series of significant challenges are looming, these include the following:

- *Nonpoint sources.* It has become apparent that along with success in managing point sources of pollution through federal technology-based treatment requirements and implementation of permitting programs, we now face the fact that a greater proportion of the impairment to our surface and groundwaters stems from nonpoint sources.

Land-use and water quality issues are inextricably linked. As urbanization proceeded, historic patterns of development caused an increase in impervious surface area that altered the patterns of runoff and increased the pollutant loadings of watersheds. These circumstances have led to

*This chapter is an edited transcript of Dr. Michael Shapiro's remarks at the workshop.

enhanced interest in concepts with names such as “smart growth” and “sustainable resource management”—basically, an approach to developing urban and urbanizing areas in ways that minimize their effects on the environment in general and on receiving waters in particular.

Agricultural practices, meanwhile, have increasingly become a focus of attention at the U.S. Environmental Protection Agency (EPA) and other agencies. To some extent, we have brought certain agricultural operations—in particular, combined animal feeding operations (CAFOs)—under the umbrella of our point source regulatory management program. However, many other agricultural practices that constitute nonpoint sources remain relatively unregulated from the federal perspective. EPA is working with the U.S. Department of Agriculture, which has considerable resources in this area, to improve agricultural practices so as to minimize the nutrient loadings and the sediment and pesticide runoff that can result from agricultural operations.

- *Emerging contaminants.* Recent studies by the U.S. Geological Survey have found that new contaminants and contaminant mixtures, such as pharmaceuticals, detergent metabolites, and natural and synthetic hormones, are appearing in our surface waters. To some degree, as our technology for detection and monitoring improves, we are finding things that perhaps have always been there, or have been there for a while, but are just now coming to our attention. In other cases, contaminants are emerging because of changes in land-use patterns, for example, or drug technology. We are only now beginning to focus attention on the significance of these findings, their implications for research, and the management issues they may ultimately pose for drinking water quality.

- *Aging infrastructure.* There is growing concern about an imminent crisis regarding the physical infrastructure of our water supply and wastewater management systems. Various estimates identify enormous gaps between current levels of expenditure to replace and upgrade that infrastructure and the amount needed simply to address issues of growth, deterioration because of age and wear, and heightened environmental standards. Depending on the study, the necessary investments could total hundreds of billions, if not trillions, of dollars.

- *Pathogens.* High concentrations of humans and of farm animals, nonpoint source runoff, greater numbers of onsite septic systems resulting from suburban growth patterns, and preexisting combined sewer systems in older urban areas all continue to inject pathogens into our source waters and pose challenges to the safety of our drinking water. Multiple

tiers of protection are needed, involving source waters and drinking water alike.

- *Water quantity and quality.* In some parts of the United States and certainly large parts of the world, the availability of safe water has become a fundamental concern. As systems become stressed in trying to provide adequate supplies of water, we will have to consider various measures for providing additional water—likely at great expense—as well as look very hard at opportunities for water conservation.

- *Governance.* Watershed protection under the Clean Water Act must be integrated with source water protection under the Safe Drinking Water Act—not just at the federal level but at the state and local levels as well. EPA is trying to promote the development of appropriate models for comprehensive decision making among all jurisdictions that take into account the needs of source water protection and other water quality-related issues.

This workshop is an opportunity to hear the perspectives of knowledgeable and expert people on these and other drinking water challenges. We hope to gain some insights on where we need to invest in additional research, where existing research has not yet been fully exploited for addressing our water protection needs, where there are opportunities for EPA and other agencies to collaborate, and where barriers must be overcome for achieving our safe drinking water goals. We hope to garner from the discussion today some good ideas on how to move forward. In any case, we regard this event as part of an ongoing process and dialogue that we wish to have, working in part through the National Academies, with all of the stakeholders in the water protection area in order to chart the best possible course for the coming century.

Workshop Objectives

*Charles Groat**

Protection of the environment is protection of health, and the theme of today's workshop demonstrates this connection very well: you cannot separate the source water from the drinking water. In the past, the relationship between water and health was often dominated by floods, which brought diseases such as cholera, dysentery, and hepatitis A that were among humanity's greatest challenges. Even diseases associated with standing water, such as malaria, often resulted from the large water influxes caused by floods.

The twentieth century, with its increased industrialization and improved agricultural processes, gave us a greater complexity of water-borne threats to human health. A wide variety of contaminants were being put into source waters and ultimately into drinking water supplies, thereby imposing a whole new set of challenges for ensuring safety.

Improvement in the monitoring networks administered by the U.S. Environmental Protection Agency, U.S. Geological Survey, and state and local agencies led to better documentation of the extent of these threats and also pointed out the need for legislation such as the Clean Water Act and the Safe Drinking Water Act. The challenges, being too broad for local governments to meet by themselves, clearly required federal standards to safeguard the quality of drinking water and protect environmental health.

Our past achievements, however responsive for their time, are still part of the past. We are now at the beginning of a new century that presents its own water-related environmental health challenges, which the public health and science communities will have to address.

*This chapter is an edited transcript of Dr. Charles Groat's remarks at the workshop.

Nonpoint source pollution, for example, is one of the greatest and most extensive threats to drinking water supplies, public and private alike. Similarly, emerging contaminants—such as complex compounds resulting from pharmaceuticals—are increasingly being identified in the surface and groundwater supply. They pose new challenges in understanding not only their evolution but their effects on human health.

Finally, it is hard to discuss health issues without thinking about September 11 or the anthrax concerns of 2001. Terrorism adds another dimension to our concerns about water supplies and the potential effects of their contamination, whether inadvertent or intentional, on human beings.

The idea for this workshop emerged from a series of discussions among Roundtable members on key issues now facing the environmental health community. The occasion gives us an opportunity to invite experts to come in and inform us about some of the current conditions, and how well we are dealing with them, and about some of the challenges we are likely to encounter—and had best be prepared for—in the future.

This workshop posed a number of very important questions to help us chart a course for the twenty-first century:

- What are the current and future challenges to ensuring public health as it relates to water issues?
 - Where is the disconnection between policy and reality—in particular between water treatment practices and scientific understanding?
 - Where is our scientific understanding deficient in its ability to inform water policy?
 - Are there additional research needs for agencies that work to safeguard public health?
 - What are the barriers to pursuing this research or to achieving the necessary improvements?

1

Status of Science and Policies for Ensuring the Protection of Source Water and Drinking Water*

The system that was put in place for delivering safe and adequate supplies of drinking water has been in existence for more than 100 years. During the ensuing century, the United States has experienced a surge in population growth, which is projected to increase until 2050. This surge represents a shift of population from sparsely populated rural areas to more densely populated urban areas and greater demands on water for multiple needs—recreation, drinking water, industrial use, and agriculture. The policy framework within which we live today was put in place prior to the challenges of our current modern day life and its suitability for the task before us—delivering safe, clean, and adequate supplies of drinking water to people—is being questioned. Lynn Goldman, professor at the Bloomberg School of Public Health, challenged speakers and participants to consider whether we are using the right paradigms and if we should continue to patch, repair, and expand the existing system or whether a new paradigm is required?

ARE THE CURRENT POLICIES ABLE TO MEET CURRENT AND FUTURE CHALLENGES?

There are many factors to consider in making risk management decisions about contaminants in drinking water, including the legal mandates and requirements, the control options, exposures, dose–response relationships, costs and benefits, laboratory methods, and agency policies, said

*This chapter was prepared by staff from the transcript of the meeting. The discussions were edited and organized around major themes to provide a more readable summary and to eliminate duplication of topics.

Frederick W. Pontius, president of Pontius Water Consultants, Inc. Such

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Lynn Goldman

decision making cannot be based on science alone. More commonly, it is a blend of science and policy. It is a mixture of different lines of reasoning, different facts, different assumptions, and different judgments made by people with different perspectives. Tracing the Safe Drinking Water Act (SDWA) from its authorization in

1974 through its various reauthorizations, Pontius posed six questions that underlie the interface of science and policy:

1. How should contaminants be selected for regulation? In 1974, when the SDWA was passed, the U.S. Environmental Protection Agency (EPA) was given discretion—general authority—to regulate contaminants. This resulted in a few regulations, such as those for trihalomethanes, but the pace was slow. So in 1986, Congress mandated regulation of 83 contaminants, whether they needed regulation or not, Pontius noted. Given this large number of required regulations, the contaminants were divided into several phases, each in turn regulating a subset of the 83. There also was a requirement in 1986 to regulate 25 contaminants every 3 years.

Inevitably, the number of contaminants regulated increased (see Figure 1.1). In the early 1990s, policy makers realized that continuing this regulatory pace—principally because of data, but also because of sheer resources—would make it impossible to meet the goals outlined in the 1986 amendment. Thus, in 1996, the law was amended again to mandate future contaminant regulation with contaminants selected from the Drinking Water Contaminant Candidate List (DWCCCL). Monitoring of unregulated contaminants was required in order to collect data to determine those that posed the greatest risk. Therefore, in the current selection process EPA considers the available data and makes a determination whether or not to regulate at least five contaminants every 5 years. Meanwhile, the standards for the 83 contaminants that were regulated as a result of the 1986 reauthorization have been retained.

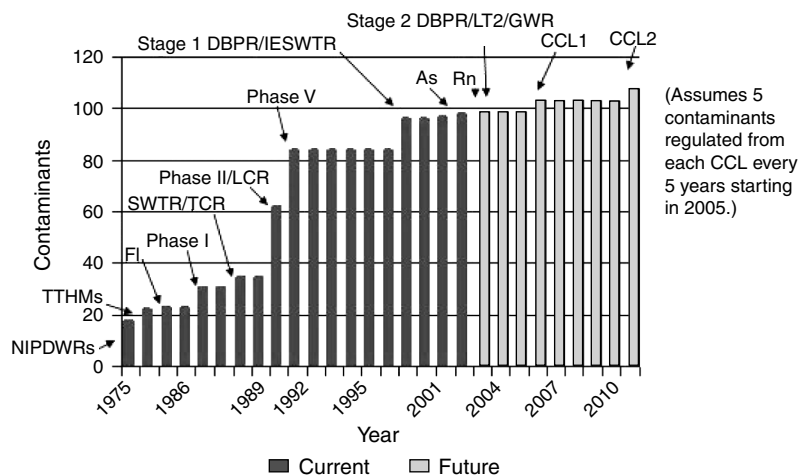


FIGURE 1.1 The number of regulated contaminants has increased since 1975. SOURCE: Pontius (unpublished). Reprinted with permission.

The EPA also applies the concept of “meaningful opportunity for risk reduction,” which was specified in the 1996 law. The agency may now conclude—especially in those cases where exposure occurs mostly through several routes (such as food, air, and water)—regulation is not warranted for numerous contaminants on the first DWCCCL because there is no meaningful opportunity for risk reduction. Under such reasoning, we take a step toward focusing our resources on those contaminants that pose the greatest risk.

The issues that we are struggling with involve data gaps, observed Pontius. Sorting through the large number of potential contaminants to identify those that pose the greatest risk is a real challenge. Currently, a Drinking Water Advisory Council committee is considering the recommendations of a National Academies report on selecting contaminants. This committee is sorting through the universe of potential contaminants to

The issues that we are struggling with involve data gaps. Sorting through the large number of potential contaminants to identify those that pose the greatest risk is a real challenge.

Frederick Pontius

develop a preliminary contaminant list. From the preliminary list, a final contaminant list will have to be developed by EPA using a transparent, scientifically sound process.

2. How should our health goals be established? In 1974, the SDWA specified the use of recommended maximum contaminant levels (RMCLs) as health goals; they were renamed Maximum Contaminant Level Goals (MCLGs) in 1986 and rendered nonenforceable, although they were based on health effects assessments with the findings expressed in criteria documents. In 1996, the health effects assessment was given specificity in the statute and a greater focus was placed on sensitive populations.

The policy for regulating a known carcinogen with an MCLG of zero was established in the 1970s and is generally applicable today. In a legal challenge regarding the agency's regulation of chloroform, the court ruled in favor of the petitioner, concluding that EPA had not used the best science. EPA is now in the throes of revising its cancer risk guidelines and a nonzero MCLG has been proposed for chloroform.

Non-cancer effects typically are based on calculations involving a reference dose (an allowable daily intake). However, its replacement with a benchmark dose (a no-observed-adverse-effect level that is the highest dosage administered that does not produce toxic effects) is something that has been considered for quite some time, said Pontius. A policy change in that direction might allow science to more consistently drive health effects assessments.

3. How should MCLs be established? The SDWA was modified in 1986 to require that maximum contaminant levels (MCLs) be set as close to the health goal as feasible, and "feasible" was defined as the use of the best technology (treatment techniques or other means). In 1996, this led to a situation, in terms of regulating those mandatory 83 contaminants, in which the MCL would be zero for known or probable carcinogens in drinking water. More pragmatically, if a treatment technology existed that could lower the contaminant level to a new threshold—a practical quantitation limit (PQL)—then the MCL would be set not at zero but at that PQL.

In 1996, more flexibility was given to EPA to consider offsetting risks and risk tradeoffs in setting MCLs in drinking water regulations, noted Pontius. The administrator must determine whether the benefits justify the costs, and if not, the regulatory limit can be adjusted to the point at which they do. We are learning, with drinking water standards

and other issues, the ramifications of proceeding in one direction when we do not know what it is ultimately going to cost. We need to consider the cost of regulation before we commit to a regulatory direction, said Pontius.

One of the main challenges for the future is whether to regulate contaminants one at a time, regulate groups of contaminants, regulate surrogates, or pursue some other approach. This is complicated by the fact that many possible contaminants could occur. Another challenge involves the regulation of small water supply systems: should they be given special consideration in terms of affordability? In both areas, additional work needs to be done.

4. *What constitutes the best science?* Science was not explicitly addressed in either the original statute of 1974 or its reauthorization of 1986. In petitions that challenged EPA's science in particular rules, the agency relied on "deference." That is, the court generally will not rule that a regulation was arbitrary and capricious unless something is obviously incorrect about it. Deference is given by the courts to the agency's judgments.

Since 1996, the statute requires EPA to use the best available peer-reviewed science in existence at the time of regulation. Yet even in meeting this standard much could still be said in terms of different perspectives, different lines of reasoning, and differences of opinions. A stakeholder always has the option to challenge a rule through a process called judicial review, but deference is given to EPA by courts, noted Pontius.

Future challenges for maintaining the use of the best science include filling data gaps, ensuring high-quality peer reviews, and applying "fair-minded thinking" to integrate differing or conflicting lines of reasoning among all stakeholders, regardless of their relative advantage. Also, the implications of underlying assumptions and presumptions must be transparent, and EPA must be willing to change its policies when justified.

5. *What is the role of source protection?* Source protection was contained in the first Safe Drinking Water Act in 1974 in the form of an underground injection control program. In 1986, the wellhead protection program was added, and in 1996, additional emphasis was placed on source protection through the source water assessment and source water petition programs. Certain aspects of Clean Water Act programs, such as TMDLs (total maximum daily loads), also have a direct application to source protection, Pontius pointed out.

6. *How can compliance be ensured?* In 1974 the primary focus was on technical assistance and establishing new state programs. There was

no federal funding for water systems, and variance and exemption provisions were included in the original law. Over the years, the emphasis on compliance also has evolved with subsequent reauthorizations. Regulatory compliance training for water systems currently is weak and must be improved.

In 1986, enforcement provisions were strengthened and a compliance period was set for 18 months. With the realization that 18 months was too short for many systems to obtain necessary financing, in 1996, compliance periods were extended to 3 years, plus 2 additional years if a system required capital improvements.

As progress is made regulatory agencies must realize that training and technical assistance are important. Although issues involving affordability for small systems can often be addressed, at least temporarily through variances and exemptions, the nation needs a better implementation of strategy for small water systems. Pontius noted that many of the current provisions embodied in the SDWA grew out of our prior failures and that if some provisions in the law are not working well, there is room for creative thinking. Also, when science advances, regulatory policies and practices must be adjusted accordingly.

ARE RECENT ADVANCES IN SCIENCE AND TECHNOLOGY ABLE TO MEET THE HEALTH CHALLENGES OF PROVIDING SAFE DRINKING WATER?

Answering the question whether science and technology are adequately providing safe drinking water requires understanding the risks that drinking water may carry, noted Jeffrey Griffiths of Tufts University School of Medicine. Many of these risks are related to the population, which is not only growing in size but changing in its characteristics—particularly with respect to enhanced sensitivity to waterborne contaminants. Thus, at the same time that water must be reused given the growing demand, it also must be purer than ever. Meanwhile, the changing activities and increasingly concentrated locations both of people and of industries have resulted in significant levels of new and emerging contaminants. These, together with agents already well established in the environment, represent approximately three million potential chemical contaminants—that calls for paradigm shifts in the ways scientists think about these issues, noted Griffiths.

Population

People are living longer, and the U.S. population is not only growing—with 275 million in the year 2000—but aging, noted Griffiths. Although there is increase in the number of young children, there also will be significant increases in the age 55+ group and, more specifically, among those 85 and older. One reason, he pointed out, is that people are living longer, including those with chronic diseases, such as diabetes (see Figure 1.2). Individuals with diabetes, asthma, or chronic heart conditions, for example, and even those with HIV are surviving much longer than in the past.

One effect of the increasing population is that the number of highly sensitive individuals and the consequent demand for very safe drinking water will increase. People are especially susceptible to infections or chemical contaminants in infancy, during pregnancy, when they undergo various medical treatments, and when they become elderly. What this means, according to Griffiths, is that at some time all individuals will be in a susceptibility group.

Geographic Concentration of People and Industries

Confounding the problem of increasing population is the increasing density of the population in urban areas. Griffiths observed that in some areas of the country, demand for water will outstrip supply—for example, in the Boston–Washington corridor. On the West coast of the United States, this situation is exacerbated because of drought conditions that further limit the availability of water. The end result is that we will have to reuse water, he predicted, even as the source waters are initially laden with waste from humans and animals. As industries such as meat production become more concentrated, land is paved over or otherwise made impermeable, and more contaminants are washed into local waters. In terms of health, this means that infectious diseases can be transmitted more easily, noted Griffiths.

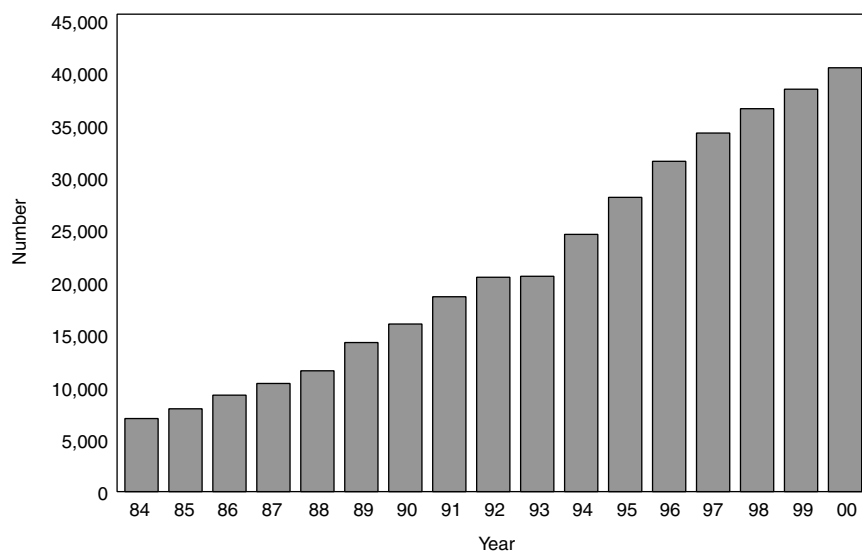


FIGURE 1.2 The number of persons initiating treatment for end-stage disease related to diabetes in the United States has risen between 1984–2000.

SOURCE: United States Renal Data System (2002). Reprinted with permission.

Emerging Contaminants

Multiple barriers have formed the cornerstone for ensuring safe drinking water. Different barriers, such as watershed protection, filtration, and disinfection, have represented critical and tremendous advancements in public health by nearly eliminating diseases such as leptospirosis, cholera, and typhoid from the United States. Newly emerging diseases are providing new challenges because some of these diseases are resistant to conventional treatment, humans as well as animals are involved in their spread, and a tiny inoculant can infect a number of people.

Jeffrey Griffiths

conventional treatment, humans as well as animals are involved in their spread, and a tiny inoculant can infect a number of people, cautioned Griffiths (see Box 1.1).

BOX 1.1
Characteristics of Emerging Diseases

- Resistance to chlorination or disinfection
- Resistance to or absence of medical treatment
- Zoonotic (animal) as well as human spread
- A tiny inoculum can infect (99 percent removal or inactivation is insufficient)
- Severe clinical disease sometimes formed only in susceptible subpopulations

SOURCE: Griffiths (unpublished from presentation).

In terms of providing safe drinking water, 99 percent removal of these pathogens can still allow for transmission of disease. *Cryptosporidium* is a good example, having caused the worst waterborne disease outbreak in U.S. history, with more than 400,000 cases of illness in 1993 and a number of deaths in the susceptible population—individuals with HIV or children with cancer. The outbreak occurred because of a failure of one filtration plant. Even though the disinfection process was still used, it was not effective against *Cryptosporidium*.

Another example is hepatitis E virus, which kills 15–25 percent of pregnant women who are infected. This pathogen is on the horizon as a serious potential health problem and is currently found in sewer systems in Spain and Washington, D.C., among other locations. Researchers have suggested that it may have made the jump from animals to humans, given the similarities between the strains in humans and swine.

As health officials confront emerging diseases such as SARS (severe acute respiratory syndrome), hepatitis E, and so forth, the public health burden may be great if one of these turns out to be a waterborne disease. Griffiths questions whether scientists and public health officials know what to look for and whether the technology available will diminish the threat. He noted that we know in part what to look for because of knowledge of the classical disease-causing agents and some of the new agents.

One limitation of the technology used for monitoring is the use of culture methods. The low concentration and the inability of some pathogens to replicate on an agar plate continue to be problems. Sensitive and specific monitoring is needed to detect pathogens, chemical compounds, and acts of bioterrorism, said Griffiths. Moreover, the system should be

inexpensive, ubiquitous, every jurisdiction should have one, no matter how rich or poor the community—and easily shared online.

For example, many people are talking about gene chips, which are used in concert with methods to amplify genetic material. Griffiths predicted that we also will have water detection chips, which will have 50,000 or 100,000 sections of nucleic acid materials to monitor the water for chemicals and toxins. Similar results also may be achieved with technologies such as optical sensors—which also could function as chemical indicators in identifying waterborne chemicals—and biosensors sensitive enough to detect one anthrax spore or one *Cryptosporidium*.

Meanwhile, Griffiths observed, it is important to continue monitoring for classical or known threats, but to remove all pathogens that get into drinking water, including the *unidentified* pathogens that cause some 80 percent of the outbreaks of waterborne disease. In addition, it is important to not leave any chemical traces and to remove naturally present but harmful chemicals such as arsenic—all while using less water and dealing with the presence of sewage and industrial waste. The challenges here are immense when it comes to health.

Conventional technology worked in 1910 and is still working today for many communities with normal populations, said Griffiths. However, it clearly has its limitations, especially for susceptible populations. Advanced technologies that can neutralize pathogens with ultraviolet radiation or pull them out with membrane technologies do exist, but they are not affordable by many systems. So we need technological advances, some of which may simply drive down the costs of present systems, though others will have to be of a different generation.

In effect, these treatment technologies should be inclusive, said Griffiths. They should monitor and eliminate across the spectrum of toxins and chemicals. They are necessary because it will be very difficult to come up with narrowly focused new treatment technologies that address one contaminant at a time—there are just too many of them and some will remain unknown. It is better, he concluded, for us to come up with solutions that essentially eliminate all of these risks at once.

2

Assessment and Management Practices: Impact on Health*

Source water protection urgently needs broad regional, state, and national attention to continue to ensure safe drinking water. During the workshop, speakers considered the complexity underlying the assessment of source water protection from a variety of threats, such as land-use patterns, nutrient loading, and agricultural practices.

SOURCE WATER ASSESSMENT AT THE STATE LEVEL

The Safe Drinking Water Act (SWDA) amendments of 1996 required the states to identify areas that provide drinking water, delineate their boundaries, register potential sources, assess their vulnerability to potential contamination, inform the public of the results, and implement a source water protection program, noted Greg Rogers of the Texas Commission on Environmental Quality (TCEQ). The 1996 amendments have included more emphasis on being proactive toward potential problems and involvement by consumers throughout the process.

With the 1996 reauthorization of SWDA, states were challenged to assess drinking water potential with regard to contamination and to develop data that could be used during monitoring. This was a challenge for most states including Texas, which has more than 6,000 water systems, close to 20,000 public water supply wells, and 600 water intakes and contains 10 percent of the nation's drinking water systems, noted

*This chapter was prepared from the transcript of the meeting by a rapporteur. The discussions were edited and organized around major themes to provide a more readable summary and to eliminate duplication of topics.

Rogers. The challenge would be to design a system that would be able to provide accurate assessment from multiple water sources.

In partnership with the U.S. Geological Survey (USGS), Texas began to develop a software system that could assist viable decisions with minimal human error, while ensuring ease of usability. The resulting system connects with the state's multimillion-record drinking water source and geographical information system (GIS) databases, giving the user a three-dimensional visual snapshot of the location or area of interest. It has enabled, for example, development of the Aquifer Atlas of Texas a mapping of all of the state's aquifers, including the multilayer aquifers that are common in Texas—derived from properties such as transmissivity, porosity, saturated thickness, and storage capacity. The system is based on accurate location information regarding the state's numerous public wells, together with details such as a well's depth, casing, and opening intervals, and it is flexible enough to adjust to various conditions such as a well's intersecting the bottom of an aquifer. Using these three-dimensional data sets the Texas team was able to model the actual effects of water draw on the aquifers. Thus, TCEQ could get more detailed than the fixed radius approach of the 1986 wellhead protection program.

Surface water assessment was more challenging because of the size of the watershed, which required that Texas look at an area of primary influence (API) or an area of primary concern, noted Rogers. By using a digital elevation model to delineate the watershed of a lake, TCEQ could identify an API, in which it wanted to be aware of potentially catastrophic effects.

To fully assess source water, knowledge of point source and non-point source contamination is required. While recognizing that knowing the locations of leaking storage tanks, oil and gas wells, and landfills is important and should continue to be monitored, there also has been recognition that nonpoint source contamination will continue to increase in influence in the future, observed Rogers. To assess the effects of non-point sources, TCEQ used multiresolution land classifications (MRLCs)—based on 20 different types of land-uses—that divided Texas into approximately 700 million 100-foot squares. These classifications formed the basis for establishing statistical relationships between land-use and water quality and further allowed for predictable equations in areas where the data were incomplete.

The Texas program is a contaminant specific assessment, which requires cataloguing the locations of potential sources of contamination (e.g., airports, landfills, gas stations) and relating specific chemicals to

each activity. From this catalogue, assessments can be developed by determining how these contamination sources intersect the capture zones. Rogers noted that the assessments include an attenuation component, based on the fact that pollutants from point sources do not always reach the well or water intake. With colleagues from the University of Texas, the program models contamination based on factors such as vertical migration, dilution of the aquifer, and properties of the chemical. Using this information, one can predict that a potential source of contamination will attenuate before it actually makes it to the well.

This software system can have numerous applications for addressing water needs at the state level, noted Rogers. This tool also can help planners look at the situation regionally; given statewide datasets, they can see a much broader picture. In the future, the software system will be used for prioritizing source water protection efforts based for instance on aquifer type, well depth, specific contamination point density, or water quality. In addition, the software and the statewide data sets allow for planning of safe source water by pre-assessing well and water intakes prior to their creation to determine if there are potential problems. As the state system evolves, there will be more local water system involvement, which will form feedback loops that produce the best and most cost-effective results of source water protection, concluded Rogers.

LAND-USE PLANNING: A CONCERN FOR SOURCE WATER PROTECTION?

Local planning is a key tool for ensuring adequate source water. In fact, good land-use planning is a preventive measure that is very protective of public health, said Douglas “Dusty” Hall of Ohio’s Miami Conservancy District. This concept parallels the shift in traditional medicine from treatment to prevention.

An essential component in a holistic approach to planning is widespread community involvement. In Ohio, the flood of 1913 resulted in

Good land-use planning is a preventive measure that is very protective of public health	a broad watershed approach to problem solving by the establishment of Conservancy Districts. The Miami Conservancy District (MCD), which contains approximately 1.5 million people in southwestern Ohio, involves many interrelated initiatives that bear on water resources and quality of life in its communities. Initiatives include
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Douglas Hall

flood protection, aquifer preservation, and river corridor improvement, as well as bikeways and other recreational amenities. The MCD, which was created by state statute, operates within a watershed-based boundary and has very broad authorities, including eminent domain. It is governed by a Conservancy Court consisting of one common pleas court judge from each of the counties within the District's official boundaries. The MCD maintains active relationships with local leaders and has created an extensive market collaborative with different local government entities, from townships to villages to counties to cities. The ability to create dialogue across government to resolve water quality problems is critical to sound water resources management, said Hall.

Meanwhile, according to Hall, MCD's core group of professional scientists translate knowledge into practice through multiple community-based groups. Virtually the entire watershed is covered by community groups composed of activists, agricultural producers, and others. By building trust through dialogue the District has been able to promote changes in land-use without government regulation.

The MCD's major metropolitan area, Dayton, provides an example of comprehensive water resources planning and management based on lessons from previous mistakes. When Dayton's first land-use plan was implemented in 1926, the connection between water resources and planning was not yet fully developed. The result was that the major public drinking water supplier's well fields were surrounded by manufacturing. Given the proximity of rivers and their utility for receiving industrial discharges the land-use plan deemed these locations well suited for manufacturers' activities—even though these very same rivers were the principal sources of recharge for the underlying and very sensitive aquifer. Thus, a comprehensive program evolved (see Box 2.1) that recognized these dilemmas and reflected a more balanced approach. Its features include an early-warning monitoring system with extensive groundwater coverage including wells near potential contaminant sources, spill reporting, time-critical response capability, and an overlay zoning district to regulate land-use. This program continues to evolve and be effective; however, changing demographics have given rise to other concerns. Ohio is using up farmland at a rate exceeded only by Texas as urbanites move to the "exurbs" that are forming at the interface between urban/suburban and predominately rural lands. This shift in population has been accompanied by an increasing reliance on household sewage treatment systems

BOX 2.1
Comprehensive Local Strategy to Ensure Water Quality

- Monitoring and enforcement
- Inventory and spill reporting
- Land-use controls
- Education
- Funding for easements
- Funding for projects
- Emergency planning and response support

SOURCE: Hall unpublished from presentation

since these areas are often not served by centralized sanitary sewer infrastructure (see Figure 2.1). Ohio's approach to regulation of household sewage treatment systems results in about 8 percent being subject to oversight. Unfortunately, the Ohio Department of Health estimates that statewide about 900,000 gallons of improperly treated sewage are being discharged each day by failing systems. This situation is exacerbated by the fact that the townships with exurban areas that are experiencing significant new growth, do not have the authority to do comprehensive planning and land-use management like cities such as Dayton. Consequently, some of the most rapidly growing areas within the state have a limited ability to handle the population growth, land-use changes, and resulting source water protection needs, noted Hall.

This is a situation in which policy makers are in danger of repeating past mistakes: they fail to undertake comprehensive land-use planning with water resources in mind. Partnerships are needed—for example, between the American Planning Association (APA) and scientific organizations—to help stakeholders understand the health linkages between shifting population and the need for comprehensive water resources planning and management. Organizations, such as Urban Land Institute, National League of Cities, and university-based urban and regional planning program such as the one at the UCLA Department of Urban Planning have developed best practice guidelines for urban and regional planning that may help to address many of these needs. The

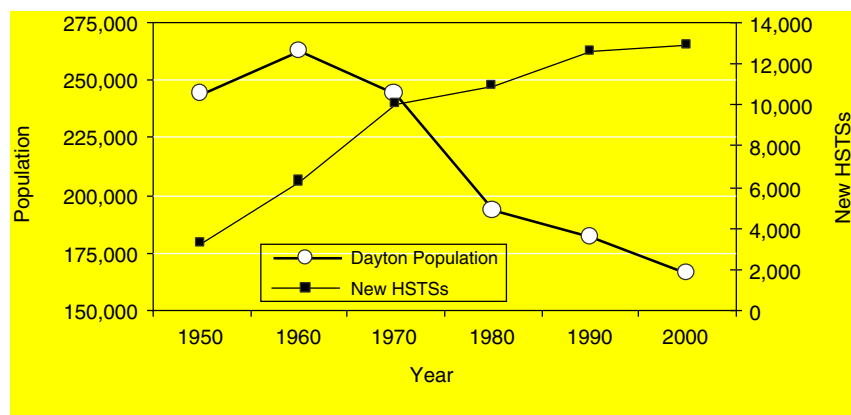


FIGURE 2.1 As the population of the City of Dayton decreases because of relocation to formerly rural areas such as in an adjacent county, there has been a greater reliance on the use of household sewage treatment systems (HSTS). SOURCES: U.S. Census Bureau and Miami County Health District (1950–2000). Reprinted with permission.

irony, according to Hall, is that some people move out of urban areas because they feel unsafe. But, they move to these exurban areas without fully understanding the different set of challenges for providing drinking water in these formerly rural areas.

IMPACTS OF NONPOINT SOURCE POLLUTION ON DRINKING WATER AND HUMAN HEALTH

Current U.S. Environmental Protection Agency (EPA) estimates suggest that approximately one-third of all assessed rivers, streams, and lakes are impaired, primarily through nonpoint source pollution, said Thomas Christensen of the U.S. Department of Agriculture's (USDA) Natural Resources Conservation Service. Although these pollutants come from many sources, agricultural practices are a significant contributor, especially in the Mississippi River basin. He noted that the USDA has a wide range of programs and tools for working with the agricultural community to improve water quality through voluntary nonpoint source management.

Types of Contamination

Agricultural pollutants include sediment, nutrients, pesticides, and pathogens (see Figure 2.2). The total comprehensive assessment of damages from agricultural pollution is lacking, although some estimates suggest that the cost is high. For example, soil erosion from agricultural lands is estimated to cost water users \$2 billion to \$8 billion annually. Nutrients such as nitrogen and phosphorus contribute to algae blooms, low dissolved oxygen, and potential health effects. Both surface water (runoff) and groundwater (leaching) are affected. In the United States, the Mississippi River basin covering all or part of 31 states has the highest potential runoff, which comes from two principal sources, animal manure and inorganic fertilizer. Nationwide, 188 public water systems (serving 748,000 people) reported violations in 1998 of EPA's nitrate maximum contaminant level.

Pesticides are another potential area of concern in many regions of the country, because many pesticides are suspected carcinogens or neurotoxicants. To date, however, the USGS' National Water Quality Assessment Program has shown low levels of pesticides in most waterways in agricultural basins, according to Christensen. He noted that integrated pest management plans can now minimize the use of pesticides through the improved timing, efficiency, and appropriateness of their application. Pathogens and pharmaceuticals are emerging water quality concerns and an area in which additional research is needed. Although there are many sources of these contaminants, the principal entry from agricultural practice is through animal wastes.

Programs for Improving Water Quality

Managing these contaminants requires the collaboration of a number of federal, state, and local agencies and many types of programs, noted Christensen, but he stressed that the states have the overall lead in water quality issues. To support the states, the USDA has many conservation programs and often more than one of these programs are employed on a particular farm. For example, in working with landowners and communities, USDA takes a natural resources conservation approach that includes voluntary, incentive-based initiatives; science-based solutions on a site-specific basis; locally led processes; informed landowner as decision

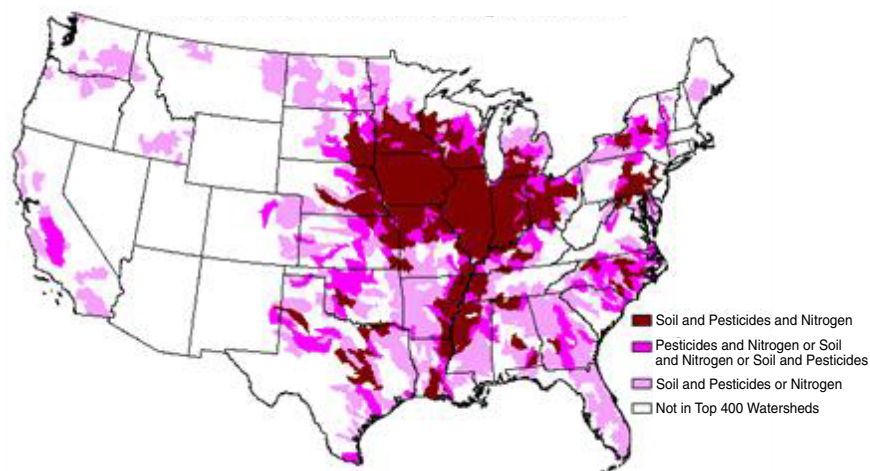


FIGURE 2.2 Watersheds with a high potential for soil, pesticide, and nitrogen runoff.

SOURCE: Ribaldo et al. (1999). Reprinted with permission.

maker; progressive implementation; adaptive management; and regulation where it is needed.

The Conservation Security Program, a new 2002 Farm Bill–specified initiative that will begin in 2004, will allow the USDA to work with farmers and ranchers to reward them for good conservation and further enhance their conservation efforts through a wide array of conservation practices—a system that makes sense for a particular operation, said Christensen. USDA has more than 160 conservation practices; all have technical standards and science behind them, including nutrient and pest management, animal waste storage, grassed waterways, and irrigation water management. These conservation practices, observed Christensen, are analogous to the well-known best management practices (BMPs) for water quality, which derive from the Clean Water Act and deal specifically with water pollution control activities.

Christensen cited a particular case study: an area of 2.2 million acres in West Virginia’s Upper Potomac River basin that has a high concentration of beef and poultry operations, which result in water quality problems from fecal bacteria. An intensive watershed planning process oc-

curred—all done on a voluntary basis with total maximum daily load (TMDL) requirements in the background—that drew on EPA and USDA programs to bring together several sources of funding and technical assistance. The result, Christensen said, was a success story. Voluntary participation on the part of landowners was approximately 85 percent, with many landowners entering into long-term contracts that obligated them to manage their poultry litter. Continued monitoring has shown that the water quality issue of fecal coliform has been reduced, and in fact the stream is now delisted; i.e., no longer on the list of impaired waters.

Lessons Learned

The USDA's decades-long involvement in the water quality arena has taught it some important lessons, noted Christensen. First, both economics and social benefits are drivers of clean water activities. Producers must make a reasonable profit to stay in business, and any activity employed has to recognize this. Second, management of land and water resources should be done on a watershed basis. Third, watershed monitoring has to be enhanced. There should be consistent quality monitoring, which will require the collaboration of all stakeholders, both public and private. Fourth, there is a need for access to water quality information and improved decision support tools.

Both economics and social benefits
are drivers of clean water activities.
Thomas Christensen

employed has to recognize this. Second, management of land and water resources should be done on a watershed basis. Third, watershed monitoring has to be enhanced. There

The adoption of BMPs for water quality improvement has its own set of requirements for success, said Christensen. Individual BMPs should be linked with effective outcomes on the quality of water in a specific water body. Similarly, these practices must make economic sense to the producer, he remarked, noting that we have not done enough to identify some of the economic benefits that might occur. Additionally, some work in the area of risk management is necessary. In many cases, producers may be unwilling to reduce the application rate of a fertilizer because they expect a reduced crop yield to result. A risk management policy could be applied: if the yields are reduced, it would make up the difference in lost benefits. Christensen concluded by suggesting that more research will be needed on the effectiveness of BMPs and the development of community-based solutions and market-based opportunities.

NUTRIENT LOADING: CRITICAL LINK IN THE CHAIN

Nutrients are regulated under both the Safe Drinking Water Act and the Clean Water Act and thus, are areas for synergic oversight. As noted above, nitrogen and phosphorus are the two nutrients of concern because of their potential health linkages. In terms of the Clean Water Act, excessive nitrogen and phosphorus loading in surface waters can be important for drinking water through toxic algal growth and the formation of trihalomethanes as a byproduct of disinfection, said Kenneth H. Reckhow of Duke University and the University of North Carolina.

Nutrient loading comes from a variety of both natural and anthropogenic point and nonpoint sources, including decaying plant material, soil erosion, bedrock weathering, wastewater treatment plants, urban runoff, agricultural runoff, and fossil fuel burning (see Figure 2.3). Understanding the processes that affect their transformations and transport has allowed scientists in a laboratory or controlled field setting to assess the critically important rates of reaction. However, despite our extensive general knowledge and awareness of sources, transformations, and transport of nitrogen and phosphorus, predictability becomes weaker when we utilize this scientific knowledge to predict outcomes in specific situations in the real world—for example, a natural water body's response to management actions such as wastewater treatment or reduction of fertilizer application rates. This can be illustrated by many river basins including North Carolina's Neuse River, which is the third largest river basin in the state, containing a large urban area with 1.5 million people living within the basin, numerous wastewater treatment plants, and a large number of contained animal feedlot operations (CAFOs).

Because CAFOs are regulated as zero-discharge facilities under the Clean Water Act, the effluent from hog pens is flushed into lagoons to be sprayed by farmers later onto their fields at allowable rates in accordance with guidelines established in consultation with North Carolina State University. There are some difficulties with this process, Reckhow noted, because of the state's vulnerability to hurricanes and other wet periods. During these times, spills can occur as lagoons breach or break, and even if they remain intact, farmers' fields become saturated and are not amenable to receiving effluent. The EPA recognizes this problem and is looking into alternatives, Reckhow said, but this remains a major contributor of nitrogen to the Neuse River basin.

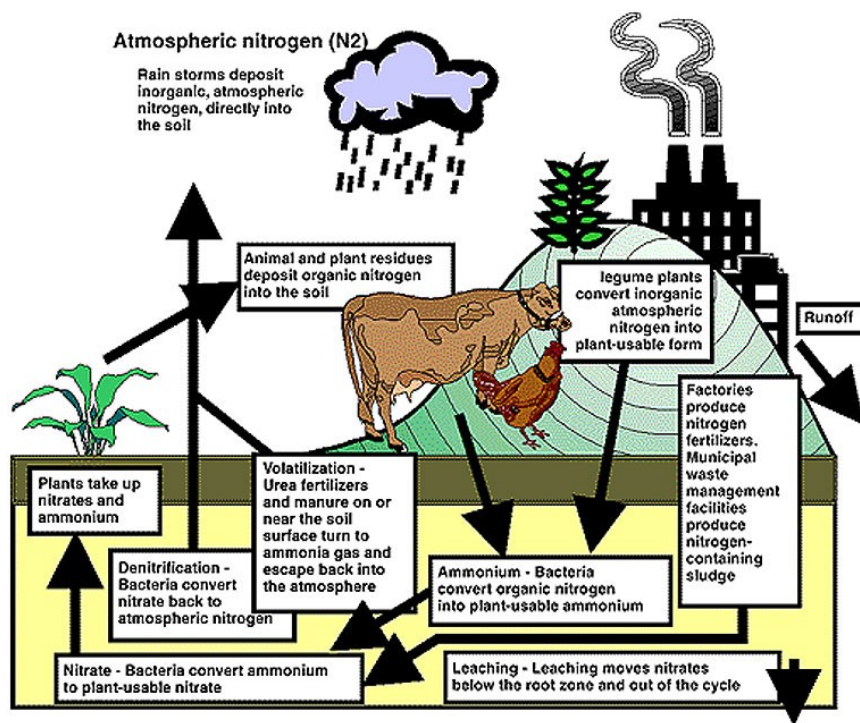


FIGURE 2.3 Nitrogen loading can occur from both natural (e.g., decaying plant material, soil erosion, bedrock weathering) and anthropogenic (wastewater treatment plants, urban runoff, agricultural runoff, and fossil fuel burning) sources.

SOURCE: University of Missouri Extension © 2004. Reprinted with permission.

As nitrogen is introduced from commercial fertilizers, manure, and wastewater and then transformed, how much of it is volatilized as ammonia and escapes as this gas? How much is denitrified and, therefore, effectively removed from contributing to algal growth in the receiving water body? How much is transported through the ground and moves readily into groundwater as nitrate? Accurate answers to these questions are not readily forthcoming, conceded Reckhow. Scientists know that

these processes occur and understand the science in the reductionist sense at the small scale. Yet when this well-established knowledge

When well-established knowledge from the lab and from textbooks is applied on the watershed scale, the current existing models do not provide the necessary reliability for making water quality decisions.

Kenneth Reckhow

from the laboratory and from textbooks is applied on the watershed scale, the current existing models do not provide the necessary reliability for making water quality decisions.

Reckhow cited two ways in which to make modest reductions in prediction error in the future:

advances in scientific knowledge that lead to increasingly elaborate and detailed models, and better observational data and enhancements in statistical techniques for extracting patterns from the data. The problem with current models is that it is difficult to capture the inherent complexity of an aquatic ecosystem and the extreme variability of nature. Yet predictions are nevertheless needed to guide decision making.

Reckhow suggested that scientists need to employ adaptive management by observing how the actual water body responds, and then use this information to augment the predictive power of the model system. He further noted that it is not improvements in models from better science, more detailed mathematics, or better data that will lead to advancement. It is the integration of the monitoring, associated with the post-implementation response of a real system, with the model forecast—an adaptive framework, in which we learn while doing—that should become common practice for these assessments, concluded Reckhow.

3

Emerging Issues in Providing Safe Drinking Water*

Chemical and biological pollutants, whether from natural or human influence, that are regulated under various state, national, and international programs represent but a small fraction of the universe of chemicals present in the environment. The majority of contaminants are not regulated; however, this does not imply that they do not pose risks, according to some participants. Some contaminants are now being recognized as emerging pollutants—for example, those that have just gained entry to the environment, because they are new to industry—while other chemicals may be ubiquitous, but recent research has questioned their risk potential. During the workshop, a panel of speakers discussed the three types of emerging waterborne pollutants: (1) chemicals deposited from the atmosphere, (2) potentially risky chemicals brought to light by our ability to identify pollutants at lower and lower concentrations, and (3) microbes that are either newly discovered pathogens or long-established agents recently rendered more virulent. They further discussed a critical need by the scientific environmental research community to establish research and development priorities for developing advanced technology for environmental detection, measurement, and monitoring instrumentation technologies.

*This chapter was prepared from the transcript of the meeting by a rapporteur. The discussions were edited and organized around major themes to provide a more readable summary and to eliminate duplication of topics.

STATUS AND TRENDS IN ATMOSPHERIC DEPOSITION OF NITROGEN AND MERCURY IN THE UNITED STATES

The hydrologic cycle, which connects surface water, groundwater, and the atmosphere, provides many opportunities for contamination of drinking water, according to Mark Nilles of the U.S. Geological Survey. The influence of contamination by atmospheric deposition can occur by both wet deposition methods (when pollutants are purged from the atmosphere by rain, snow, sleet, or fog) and dry deposition methods, (e.g., gas and particle removal) in the absence of precipitation through gravity and uptake by vegetation. Three such chemicals—ammonia, nitrates, and mercury—can affect human health when nitrates and ammonia enrich aquatic ecosystems in excess and mercury bioaccumulates in aquatic food chains. With specific regard to these three contaminants, Nilles presented status and trend data derived from the National Atmospheric Deposition Program's National Trends Network—a collection of monitoring sites spread across the nation—which is supported by numerous contributors both public and private, including a wide range of federal and state agencies. A long-term network with multiple sites, it enables researchers from many agencies to use the data to correlate emission trends with potential sources and human and ecological endpoints.

Ammonia

The U.S. Environmental Protection Agency's (EPA's) *National Air Quality and Emissions Trends 1999* report revealed that ammonia emissions in the United States derive largely from agriculture, with approximately 72 percent from livestock and 16 percent from fertilizer application. This is atypical among dominant anthropogenic contaminants because the association or reported association is not from fossil fuel oxidation. Of 149 sites monitored for ammonia, 64 reported an increase in the rate of ammonium deposition, which was not associated with any particular region of the country. The status in 2002 was that ammonium ion wet deposition (see Figure 3.1) had a background deposition rate of approximately 0.2 kg per hectare. In primarily rural regions such as the Mississippi River basin, the level rose to approximately 5 kg per hectare.

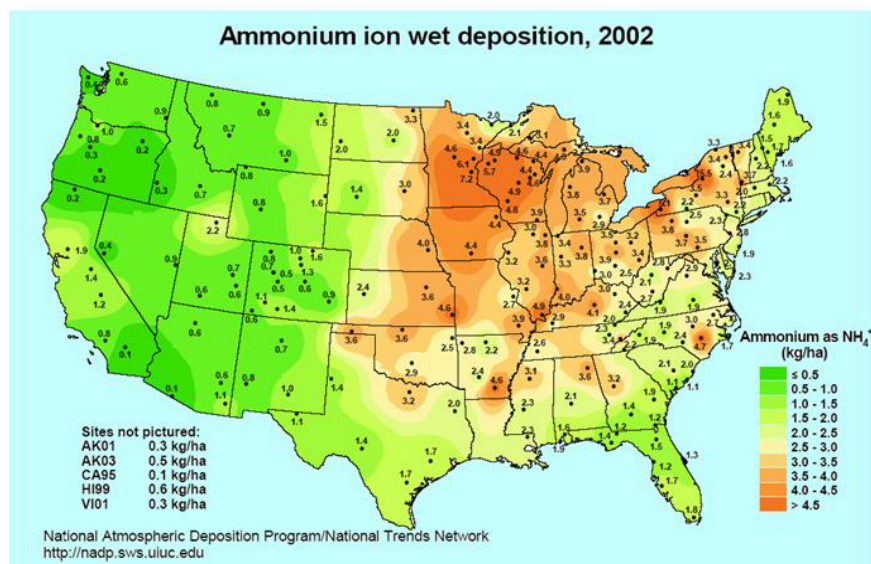


FIGURE 3.1 Ammonium ion wet deposition, 2002.

SOURCE: National Atmospheric Deposition Program, National Trends Network (NADP/NTN) (2004). Reprinted with permission.

Mercury

Mercury deposition, however, differs from both ammonia and nitrogen oxide depositions in its concentration and association. Mercury deposition is more complex, and comes from a wide variety of sources, the top four being utility coal boilers (40 percent), medical and municipal waste incineration (12 percent), other industrial boilers and heaters (10 percent), and chlorine production (5 percent). Highest concentrations in precipitation are observed in the Indiana-Minnesota-Wisconsin corridor whereas highest deposition is observed in the southeastern United States—a result of elevated concentration and greater amount of precipitation.

The trends for mercury are essentially indeterminate; however, because atmospheric deposition monitoring has not been established for long enough to determine trends, even though such deposition can account for some 50 to 75 percent of the mercury input to most aquatic ecosystems. EPA's fish advisories on mercury have increased dramati-

cally in the last 10 years and now dominate fish consumption advisories in the United States (see Figure 3.2).

Nitrate

Whereas ammonia emissions correlate with agricultural areas, nitrogen oxides are strongly associated with industrial activities. Nitrogen oxide emissions are dominated by fossil fuel combustion, with transportation contributing 49 percent; utilities 27 percent; and industrial, commercial, or residential sources 19 percent. The highest concentrations of nitrogen oxide deposition are near areas of significant industrial activity and fossil fuel combustion, such as California, noted Nilles. The long-term trends have shown a slight increase in nitrate in the West, while the northeastern United States has experienced a downward trend; however, few of these trends are environmentally significant, concluded Nilles (see Figure 3.3).

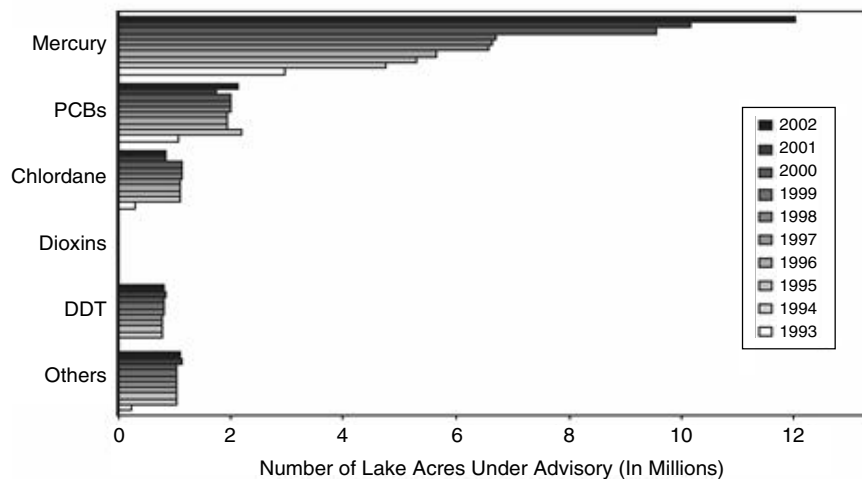


FIGURE 3.2 While the number of lakes under advisory for a number of contaminants has remained relatively steady since 1993, mercury advisories have risen threefold.

SOURCE: Nilles (unpublished). Reprinted with permission.

Moreover, even though nitrogen deposition rates in the farm states are relatively high compared to those of nonagricultural regions, the percentage of total nitrogen input in the Midwest is low because direct runoff from fertilizer application is higher in these regions. Therefore, while approximately 19 percent of the total nitrogen in New York and Connecticut's Long Island Sound comes from atmospheric deposition, this phenomenon accounts for less than 5 percent in the Mississippi River as well as in other water bodies in that region.

NONREGULATED CONTAMINANTS: OLD POLLUTANTS, NEW CONCERNS; NEW POLLUTANTS, UNKNOWN ISSUES

Although some emerging pollutants have recently been released into the environment, it is important to recognize that the vast majority of

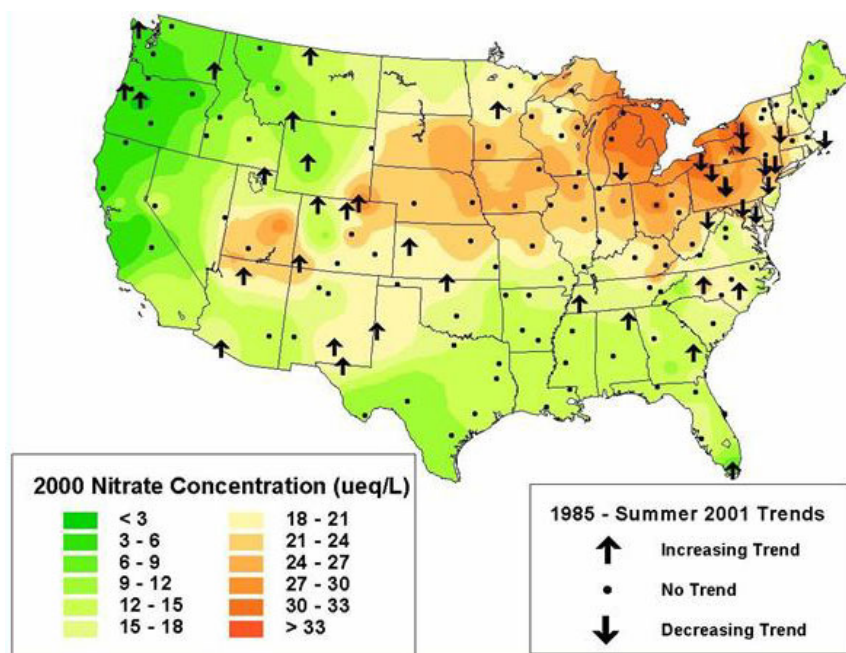


FIGURE 3.3 U.S. nitrate trends in precipitation have shown some sites in the United States (the West) with modest increases in concentration, while other regions have shown slight decreases.

SOURCE: USEPA (2003). Reprinted with permission.

recently identified potential pollutants were previously unrecognized and are of interest as a result of advances in chemical analysis—our ability to identify pollutants at lower and lower concentrations, said Christian Daughton of the EPA. Daughton noted that there are more than 22 million known organic and inorganic substances, of which nearly 6 million are commercially available. Yet only 250,000 of those 6 million—about 1 percent of the known chemical universe—have been inventoried or regulated by any countries throughout the world.

The agenda for regulation is far narrower still. Since the 1970s, it has focused almost exclusively on conventional pollutants such as persistent, bioaccumulative, toxic (PBT) pollutants; persistent organic pollutants (POPs); or bioaccumulative chemicals of concern (BCCs)—a subset of which are the “dirty-dozen” halogenated organics including DDT (dichlorodiphenyltrichloroethane) and PCBs (polychlorinated biphenyls). These pollutants are only one small piece of the larger risk puzzle, said Daughton. Many other chemicals, including a number of consumer goods and pharmaceutical agents, have routinely been neglected, ignored, or omitted. Yet because this latter category is for all practical purposes unlimited, thresholds must be established in practice.

Given the wide range of pollutants to which an organism is exposed, for example, as a result of drinking water, some portion of the overall risk derives from unregulated pollutants, which compose the majority of chemicals in any water sample.

Scientists need to reevaluate what constitutes persistence. Chemicals that have short environmental half-lives can still be persistent if they are continually reintroduced into water.

Christian Daughton

Not all of them are necessarily harmful, noted Daughton. While assessing this risk, one must remember that not everything that can be measured is worth measuring and not everything worth measuring is measurable. There

are multiple dimensions to consider in assessing holistic risk posed by exposure. According to Daughton, the four most important of these dimensions, called the four Ts, are *toxicants* (i.e., their identities), *totality* of the chemicals or doses, *tolerance* (i.e., resistance of homeostasis to perturbations), and *trajectory* (i.e., dynamic variations in stressor types and concentrations over time). All together, they form the foundation for understanding the overall true risk, which at present no one is really capable of determining. Ascertaining the toxicological significance of multiple trace-level exposures will require a better understanding of factors such as additive effects, interactive effects including synergisms, and

nontarget species receptor repertoires. For example, drugs, which were not developed for any organism in the environment other than people or domestic animals, could have numerous mechanisms of action in diverse niches of ecological cycles that ultimately affect humans. Moreover, scientists need to reevaluate what constitutes persistence, said Daughton. Chemicals that have short environmental half-lives can still be persistent if they are continually reintroduced into water, for example, via sewage.

Meanwhile, as researchers seek the important missing pieces of the larger holistic risk puzzle, we should employ early-warning water monitoring. Based on change detection, this would not target an impossibly long and ever-growing list of target analyses but would respond only to contaminants that are newly present. For example, a low-cost, rapid monitoring system could be deployed nationwide for detecting unanticipated effects of technology on the environment. Early-warning water monitoring also could be very useful with respect to homeland security, suggested Daughton, because it would minimize the chances of widespread effects resulting from surreptitious sabotage of water systems and would be very important for maintaining and solidifying public trust in water supplies. Ultimately, after-the-fact detection and remediation should be supplanted by pollution prevention and stewardship programs, which also can be less costly. Unfortunately, the drinking water and wastewater infrastructures—which are critical to such programs—have both been decaying. A study by the American Society of Civil Engineers, for example, concluded that these infrastructures currently merit nationwide grades of D and that \$20 billion would be required annually merely to keep them where they are right now without further decay.

It is a question not only of securing the needed financial resources, noted Daughton, but of maintaining and improving the public's confidence in water supplies. It is important that we maintain the public's trust in order to successfully respond to the growing pressures to reuse wastewaters for drinking. The two major issues in this area are (1) *groundwater recharge*, whether direct or indirect and (2) *decentralized water reuse*, the epitome of which is referred to as "toilet-to-tap" programs. Taking water from the toilet, treating it onsite, and reusing it as drinking water would obviously be the ultimate, though not untypical, application. Technologically, this is feasible but the question is: Would the public ever accept it? Daughton suggested that the public would, as long as the communication of risk—low risk, in this case—is given greater priority. This highlights the need for scientists to better convey the significance of their work to the public. It is very important that we discern better ways

to get scientists engaged in doing so, especially with regard to resolving the sometimes diametrically opposed views of risks held by scientists and the public. This has to do with the difference between real hazards and risk perception. One way of addressing this disconnect, proposed Daughton, would be to involve the cognitive science community substantively. Social scientists and psychologists should be used more frequently in helping to bridge this gap in communication between scientists and the public, however, getting bench researchers to collaborate and communicate more fully with social scientists would be a challenge in its own right.

PATHOGENS IN WATER: ADDRESSING A PUBLIC HEALTH THREAT VIA THE POTENTIAL SYNERGISM OF THE CLEAN WATER ACT AND THE SAFE DRINKING WATER ACT

It has been 10 years since the deadly *Cryptosporidium* outbreaks in water supplies, observed Joan Rose of Michigan State University, but we have not made as much progress during those years as we could have in addressing emerging waterborne pathogens. The zoonotic class of waterborne pathogen, of which *Cryptosporidium* is a classic example, is excreted in large numbers by humans and animals, survives very well in the environment, and is resistant to water treatment (see Figure 3.4).

These emerging pathogens, derived largely from fecal waste in sewage discharges, septic tanks, combined sewer overflows, stormwater, and

Societal changes, occurring in both the developing and developed worlds, have contributed to greater exposure or susceptibility to emerging diseases or diseases previously thought to be under control.

Joan Rose

agricultural runoff, are of concern for both wastewater treatment and drinking water treatment. Therefore, they must be regulated by the Clean Water Act as well as the Safe Drinking Water Act, which to date have only spottily addressed pathogens and have

largely failed to complement each other, asserted Rose.

In industrialized countries, public health has made significant progress in containing and eliminating outbreaks as a result of infectious agents. However, noted Rose, many societal changes, occurring in both the developing and the developed worlds, have contributed to greater

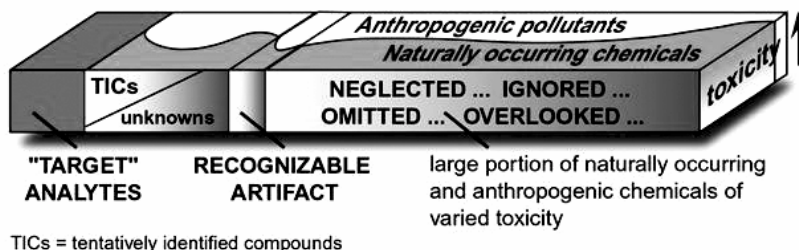


FIGURE 3.4 Chemical analysis output for a typical environmental sample. SOURCE: Daughton (2002). U.S. Environmental Protection Agency. Reprinted with permission.

exposure or susceptibility to emerging diseases or diseases previously thought to be under control. Drivers of increased risk of waterborne pathogens in particular include population growth and demographic changes, associated with increased generation and concentration of human wastes; the aging wastewater and drinking water infrastructures; greater exposure to emerging zoonotic agents; and climate change with precipitation, wind, and temperature shifts aiding in the transport and survival of the contaminants (see Figure 3.5).

Given these societal changes or circumstances, outbreaks of infectious disease do and will occur. Also, although scientific and public health professionals have generally been able to control major outbreaks, these outbreaks are estimated to account for only 5–10 percent of the waterborne disease in any community, and they are increasing according to the latest statistics from the Centers for Disease Control and Prevention (see Figure 3.6). Numerous outbreaks continue to occur in the smaller water supply systems, which do not have as much opportunity for monitoring or investing in treatment technology and upgrades, for both groundwater and ambient waters.

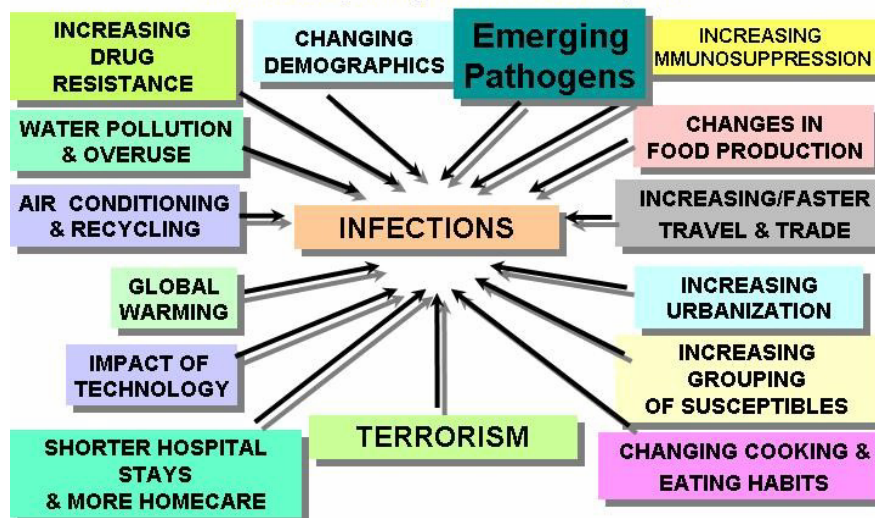


FIGURE 3.5 Known or potential impact of societal changes on susceptibility to infectious agents.
 SOURCE: Sattar (2002). Reprinted with permission.

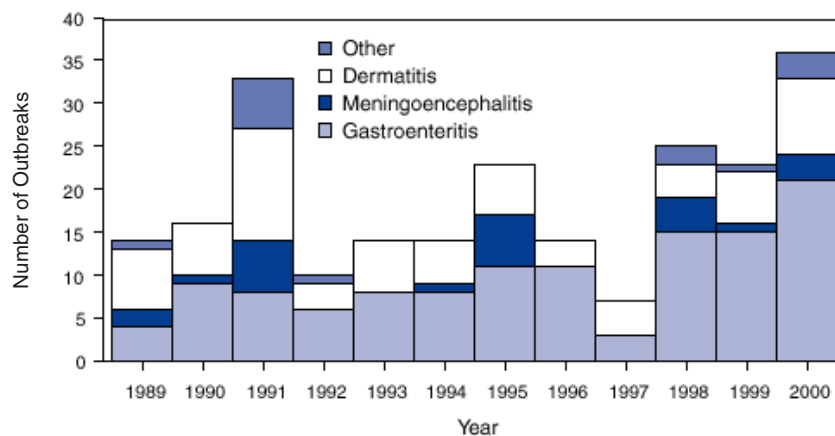


FIGURE 3.6 Since 1996, the number of waterborne pathogen outbreaks in the United States has increased.
 SOURCE: Lee et al. (2002).

Meanwhile, knowledge of microorganisms on EPA's current Contaminant Candidate List has not proceeded very far, according to Rose, because there has not been sufficient investment in understanding the occurrence of these contaminants in water, the potential for exposure, and the health outcomes. Yet even if progress had indeed been made in terms of these pathogens, it would be only the beginning. We have cultivated approximately 1 percent of the organisms that might be found in wastewater (i.e., from the intestinal tract) and might be associated with disease. In addition to the new pathogens being discovered every year, researchers are learning not only of the roles of infectious agents in health risk end points such as diarrhea, but also of the increasing role of infectious agents in chronic diseases such as ulcers, Guillain-Barré syndrome, and some cancers.

Many of the emerging pathogenic bacteria—including *Campylobacter*, *Salmonella*, *Cryptosporidium*, *Giardia*, *Mycobacterium paratuberculosis*, and new and deadly forms of the ubiquitous *Escherichia coli*—are zoonotic. Even a traditional pathogen like *Salmonella* is showing up in a new bovine form, called *Salmonella newport*, that constitutes approximately 10 percent of all human *Salmonella* infections, yet is resistant to numerous antibiotics. These pathogens, and hundreds of others associated with animal wastes, are now present in human sewage. Similarly, wastewaters contain some 130 viruses that are enteric, respiratory, or both, reported Rose. Coxsackie viruses in particular, which cause not only diarrhea and respiratory disease but myocarditis, diabetes, encephalitis, and meningitis, are the most common. Adenoviruses also are being found in high concentrations in wastewater, as well as in tap water. These pathogens are a great concern or risk for small communities and for those individuals reliant on groundwater—groups that are already seeing an increase in the number of outbreaks—of both in respect to acute and chronic diseases.

As we move forward, we will face a number of challenges, concluded Rose, including the following:

1. To engineer ultraviolet (UV) disinfection to be effective against pathogens such as adenoviruses, which are now largely resistant to it. This is paramount because UV has been displacing chlorination, whose discharges are seen to be environmentally damaging.
2. To study certain cancer-causing viruses, polyoma viruses, now being found in sewage at fairly high concentrations. Little is known about these single-stranded DNA viruses' survival or resistance to

wastewater treatment or wastewater disinfection and of the role of water in transmission of the viruses.

3. To develop the research agenda to include studies of sources, transport, ambient waters, and groundwaters and to focus on risk outcomes.

4. To complement in practice two inherently related but often separately administered pieces of legislation namely, the Clean Water Act (CWA), which addresses human health largely through recreational exposure and the Safe Drinking Water Act (SDWA), which addresses human health through exposure to tap water.

The CWA focus has been reactive, with epidemiological data used to set national guidelines, while regulation under the SDWA has established a Maximum Contaminant Level Goal of zero tolerance for pathogens, followed by treatment technology. The SDWA assumes that all waters are at risk, said Rose, and that if we treat the water appropriately, we are going to be safe.

Pathogen monitoring and risk assessment have been done under the CWA, but for ecological end points and not public health. With the SDWA, by contrast, monitoring and risk assessment have been used extensively, and sensitive populations have been included. Neither act has begun regulating emerging pathogens, she noted, although the SDWA has included them on its Contaminant Candidate List for analysis of occurrence and health risk.

The CWA does offer an abundance of watershed tools, however, for examining the effects of combined animal feeding operations, sanitary sewer overflows, combined sewer overflows, and septic tanks on public health. If we focus on the watershed tools that the Clean Water Act provides and continue through the continuum of using a risk assessment approach, together with better monitoring to identify contaminants of concern, we are going to emerge with the ability to put our dollars where we need them, said Rose. We will better protect our waters from the perspective of both the Clean Water Act and the Safe Drinking Water Act and be able to achieve long-term water quality sustainability as well.

4

Change: Implications at the Water–Human Health Interface

*Peter Gleick**

The United Nations designated 2003 as the year of fresh water, which reaches across many academic and institutional fields and across political borders. Water has a broad influence on human health and ecosystem health and it is clear that its importance in the policy and health arena will continue to grow in the coming decades. Water challenges are complex, requiring the adoption of alternative paradigms across the globe for water policy, planning, and management.

Central to the rising demands on water is the increase in population growth. The per capita availability of water across the planet is going down, because the population is increasing while the total amount of water

The per capita availability of water across the planet is going down, because the population is increasing while the total amount of water is static.

Peter Gleick

on the planet is static. In some regions, the complementary rise in population and reduction in water availability are occurring rapidly. This problem is compounded by taxing an already vulnerable system in areas where the natural endowment is naturally low. The increasing demands with population growth are more problematic when one considers that the per capita demand for water—the amount we use per person for the things we want to do—is rising in many regions, driven by economic growth.

Population growth adds other pressures to a tightly intertwined ecosystem. As the population grows, additional demands on natural resources and shifting of land-use patterns occur to meet the basic needs of

*This chapter is an edited transcript of Dr. Peter Gleick's remarks at the workshop.

populations. Currently, the amount of irrigated land worldwide is still growing, but because the population is growing even faster, per capita irrigated land area is decreasing. This has enormous implications for food production, because it places increasing pressure on available resources—particularly fertilizers and pesticides—to get greater yield out of every hectare in production.

Furthermore, we are seeing a swift and irreversible ecological change in aquatic ecosystems. Many fish species are threatened or endangered, and some aquatic ecosystems have been altered or destroyed completely. The issue of climate change is perhaps the quintessential global change issue, with enormous—and not completely understood—implications for water. It is clear, however, that as competition for fresh water grows, not only between regions but between different sectors within regions, political tensions and conflicts inevitably occur.

Approximately 1.1 billion of the world's people do not have access to clean drinking water and 2.4 billion people—40 percent of the global population—lack adequate sanitation services.

Peter Gleick

All of the changes in the ecosystem are important, but the fact remains that we are already having problems meeting the water demands of our population. Approximately 1.1 billion people do not have access to clean drinking water and 2.4 billion people—40 percent of the global population—lack adequate sanitation services. These failures to meet basic human needs for water lead to hundreds of millions of cases of water-related diseases—cholera, dysentery, schistosomiasis, guinea worm—every year. The United States and Western Europe eliminated these diseases long ago, but they remain major problems in many parts of the world.

In the United States and Western Europe, our water quality challenges have shifted toward persistent chemicals, hormones, pharmaceuticals, and trace elements. Unsustainable groundwater overdraft is occurring in many parts of the world: groundwater is being pumped faster than it is naturally being recharged. This is a problem in California, India, and many other places around the world. In some cases, this is accelerating the deterioration of

Unsustainable groundwater overdraft is occurring in many parts of the world: groundwater is being pumped faster than it is naturally being recharged.

Peter Gleick

fresh water grows, not only between regions but between different sectors within regions, political tensions and conflicts inevitably occur.

groundwater quality; as we pump the water faster and faster, contaminants may spread more rapidly through aquifers.

Many observers describe these water problems as a crisis, not localized in particular regions but on a global scale. The unmet basic needs for water—those 1.1 billion people without clean drinking water and 2.4 billion people with inadequate sanitation services—continue to take their toll. This omission, arguably the greatest development failure of the twentieth century, now haunts the twenty-first century, notably in humanity's burden of water-related diseases. The World Health Organization's current estimate is that two million to five million deaths a year are caused by these diseases, virtually all of which are preventable.

This issue is not unknown. In fact, two of the Millennium Development Goals set in 2000 by the United Nations and the world development community explicitly address water. They aim to reduce by half the proportion of people without access to clean water and to reduce by half the proportion that lack sanitation services, by 2015. However, these aggressive goals, though well-intentioned, are not likely to be met. The level of commitment on the part of the principal actors—governments, intergovernmental organizations, international financial institutions, and nongovernmental organizations (NGOs)—is simply insufficient. For example, total overseas development assistance (ODA) in the water supply and sanitation sector—all aid from developed countries plus all aid from international financial institutions such as the International Monetary Fund and the World Bank—is decreasing.

One example is the United States, which gives the smallest amount of water aid as a fraction of its gross national product (GNP) of any of the developed countries. Its total water aid is about \$400 million, which goes to 14 countries, mostly in the Middle East. All U.S. ODA to Africa in water supply and sanitation in 2001 amounted to only \$5 million to \$10 million. Yet it is not just money that is required. The United States has enormous educational resources, technological resources, and many other resources that could be contributing to the solution.

The twentieth century was a time in which water demand was met through increased water supply. Governments built dams, aqueducts, reservoirs, and pipelines, and water was taken from the environment without really understanding the ecological implications of these actions. Thus, there has been ecosystem collapse and con-

As we have failed to meet basic human needs for water, we similarly have failed to meet environmental needs for water.

Peter Gleick

met through increased water supply. Governments built dams, aqueducts, reservoirs, and pipelines, and water was taken from the environment without really understanding the ecological implications of these actions. Thus, there has been ecosystem collapse and con-

tamination because dams modify river flows, temperatures, and water quality; trap sediments that prevent the recharge of deltas; and jeopardize the fisheries that depend on them. More than 20 percent of North American freshwater fauna are now considered threatened or endangered because adequate flows do not reach the deltas of many major rivers.

These are old, although unfortunately continuing, trends, particularly in the developing world, but there also are new concerns. Recently in India, for example, a small environmental group released a study of pesticides in Indian bottled beverages. The group bought the products from 10 different beverage companies and reported that each sample had pesticide levels above acceptable standards. In governmental tests, the results turned out to be the similar. The conclusion is clear: there are pesticides in the beverages from bottling companies in India.

In hindsight, it should be no surprise that there is a pesticide problem with Indian bottled beverages. It is a problem in the United States, why shouldn't it be a problem elsewhere? There are pesticides in source waters across the planet. In developing countries, which now face these kinds of new problems in addition to old problems, the financial and institutional resources to adequately address either of them are lacking.

We must now add to all this the looming effects of climate change. Although there are many things we still don't know for sure—the timing, location, and extent of regional climate effects, the cost of doing something about them; the cost of not doing something about them; the consequences of the Kyoto agreement; we are increasingly sure that some major climate changes will occur. Indeed, we are already seeing evidence of climate changes and it will clearly have important, and likely adverse, effects on the hydrologic cycle and on the systems that have been built to provide us with clean drinking water supplies and with sanitation services.

We need a new paradigm offering a fresh way of thinking about water management and policy. The problem is not just that we haven't

We need a new paradigm—fresh ways of thinking about water management and policy.

Peter Gleick

built enough water supply and sanitation systems in developing countries, although that is true in some places. I would argue, however, that we are often advocating and undertaking the wrong pro-

grams. The infrastructure we have established here in the United States and elsewhere in the developed world may not be a better way to address basic needs for water supply and sanitation in developing countries. For

example, we are not going to meet basic needs for drinking water and sanitation services solely with centralized infrastructure, with the kinds of wastewater treatment plants that our large engineering companies know how to build and sell and that our large financial institutions know how to fund. In certain urban areas these kinds of systems could be the most appropriate. However, we may need other systems in other locations, such as community-scaled and community-managed water supply systems.

Sometimes we need things such as point-of-use purification, rain-water harvesting, or non-water-based sanitation, options that may be low tech but can still be science-based, rigorous, and successful. Contrary to conventional wisdom, which holds that we cannot depend on the individual household to disinfect its water, sometimes small-scale decentralized options are more reliable.

Ultimately, a new paradigm will be adopted on a global scale only if it becomes established within the major funding institutions. The World Bank, for example, understands very well how to evaluate, support, and fund large infrastructure; it excels at large, concentrated efforts rather than numerous small initiatives. We have to be more creative about modifying established mechanisms, or creating new ones, to finance such programs.

In that spirit, I offer what I believe are the necessary priorities:

- We have to meet the basic human needs of water for everyone. This is a fundamental human right. The Millennium Development Goals are an effort to push government policy in this direction, but they need more support.
- Smart use of existing infrastructure is critical. We have a substantial network of infrastructure in existence, but it has to be operated in different ways, especially under conditions of climate change. Until recently, water managers were trained to assume that the future would look like the past. If we had 50 years of hydrologic records, for example, hydrologists would be able to produce the statistics that told us the probabilities of floods and droughts and we could then operate our reservoirs accordingly. Now, however, the climatologists are telling us that the future is not going to look like the past. We will have to plan differently and use available tools in new and imaginative ways.
- In most places, efficient use of water should take precedence over new supply. This does not mean brown lawns and fewer showers or not flushing our toilet as often as we would like. It means meeting our

needs with less water. The fact is that water use under routine conditions tends to be enormously inefficient. Even in California, despite the programs that have already been put in place—some of which are quite innovative—a recent study by the Pacific Institute in Oakland found that the state could reduce urban water use 30 percent merely by deploying existing technology more effectively.

- We need to rethink what we mean by supply. Water supply doesn't just mean a new, large, centralized infrastructure. Supply also can mean thinking of reclaimed and recycled water as an asset instead of a liability. Reclaimed water is valuable for groundwater recharge, power plant cooling, municipal landscapes, and some kinds of irrigation, among other uses. By better matching the demand for water with the quality of water, supply takes on an entirely different meaning. All of a sudden, there is a lot more water out there.

- We need to make wider and more reliable, commitments of resources. We are not meeting our stated funding commitments, but even if we did, they would still be too low. It is not just a question of money, however, but of technology, training, and institutional capacity-building. There are many additional programs we can adopt that transcend the purely monetary.

- When we do spend money, we have to vary what we fund and where we fund it.

- We need to support different programs and explore opportunities in different areas and, in some cases, work with different kinds of agencies such as NGOs and smaller-scale agencies to develop community-level water-management systems. There is a lot of expertise; it is just not in the areas that we traditionally fund.

Essentially, we have to shift to a new way of thinking about

Ingenuity is universal and industrialized nations should not only assist developing nations as much as possible but also learn from them.

Peter Gleick

water, especially regarding its connections with human health.

One way is to profit from the experiences of other countries, recognizing that ingenuity is universal and industrialized nations should not only assist developing nations as much as possible but

also learn from them. South Africa, for example, has excelled at integrating ecological restoration and protection as a fundamental part of water policy. The nation's constitution explicitly guarantees meeting the basic

water requirements of all residents and ecosystems through a water “reserve”—a science-based program that reflects high but realistic standards and detailed knowledge of local environmental conditions. Botswana is another country that truly understands the value of its environmental flows, motivated by its economic reliance on ecological tourism.

Similarly, developed countries have much to teach us about smaller-scale community water systems, which have a long history but were largely pushed aside in the last century when the perception was that the developed world had all the answers. Many small-scale systems have proven to work at the community level—and to work at high efficiency—in the developing and developed worlds alike.

There are many connections between water policy and human health, and they are complex. This requires that our approaches to addressing them also be complex—our systems have to be multiple and varied. Despite the challenges, these goals are achievable and well worth the effort.

5

Charting a Course for the Future*

The workshop provided an opportunity for the Roundtable to hear presentations on the totality of water issues. Many participants agreed that we have made progress since the passage of the Safe Drinking Water Act and the Clean Water Act because they were instrumental in providing the first steps to ensure the availability of water for current and future populations. Henry Falk, assistant administrator of the Agency for Toxic Substances and Disease Registry (ATSDR) and director of the National Center for Environmental Health (NCEH) at the Centers for Disease Control and Prevention (CDC), observed that these regulations served as a means to enact some of the most beneficial and readily available measures. However, he noted that the remaining issues are complex, often have societal and personal implications, and are not fixed by quick regulatory decision. Panelists and participants discussed many of these issues including a paradigm shift, research needs, educational needs, and other challenges ahead.

DO WE NEED A NEW PARADIGM?

In the mid-1800s, the United States and other countries adopted the use of water as a means of disposal of agricultural, industrial, and human waste. It was necessary to address the public health burden of the time. To avoid leaving waste in the street, the rivers provided a mechanism for the removal of waste from our cities. This worked well for the time,

*This chapter was prepared from the transcript of the meeting by a rapporteur. The discussions were edited and organized around major themes to provide a more readable summary and to eliminate duplication of topics.

noted Lynn Goldman, professor, Bloomberg School of Public Health, but we have reached the point where it is no longer feasible; yet we have built a large infrastructure to support this method of water usage. The question remains whether the approaches we are using (multiple uses of water, including waste disposal) are feasible as we face a growth in population and increased consumption per capita.

One of the workshop participants, noted that part of the paradigm shift would be the integration of individuals across disciplines and agencies and suggested that taking an issue such as pathogens or drinking water source protection as a focal point and bringing together the agencies, disciplines, and regulations to address the issue as a whole instead of piecemeal, would be a starting point. Kenneth Reckhow further suggested that two strategies for providing safe drinking water involve treatment and watershed protection. He noted that it is conceivable that we will not have to identify all of the chemicals and pathogens in waters, as membrane or activated carbon might effectively remove them. One problem is that drinking water comes from various sources, including individual household wells. He noted that appropriate treatment at a household level may be problematic.

Susan Seacrest agreed that any paradigm will not be a product of “one-stop shopping.” It isn’t realistic to wait for any one agency to address all aspects of water safety. Cynthia Dougherty, Office of Ground Water and Drinking Water of the U.S. Environmental Protection Agency (EPA), noted that some of the work will have to be undertaken at the national level—for example, the establishment of national criteria for pathogens—while other approaches will occur at the state and local levels such as land-use policies and identifying which surface waters also are drinking water sources. Seacrest agreed and noted there is a role for everyone, with important roles for everyone to play. She reiterated that it is important to identify various roles, and various tools, and to reinforce a sense of responsibility about our drinking water. Public health officials from the local to the national level have to be continually engaged, noted many panelists, and we need to find ways of including them.

WATER AS A COMMODITY

As a starting point, some panelists reinforced the idea that the monetary value of water is a very important issue that is often underestimated. Wastewater treatment is costly, especially with regard to reclaiming wa-

ter for beneficial purposes. Nevertheless, water is greatly undervalued and subsequently underpriced. Until the economic value of water is taken seriously into account and appropriately adjusted, decision makers—national, regional, and local—will not have a strong incentive to treat this resource with greater respect, noted many panelists.

Christine L. Moe of Emory University suggested that we in the United States really need to change our attitude toward conservation; we should follow our colleagues overseas, especially in Europe, who are very aware of their resource limitations. In our country, by contrast, we have had an abundance of natural resources and we keep living as if they will never end. The level of water consumption per capita, for example, is far greater in the United States than in European countries, even though the corresponding standards of living are more or less the same, noted Moe. This high level of consumption simply is not sustainable.

YOUR WASTEWATER IS SOMEONE ELSE'S DRINKING WATER

Another critical issue is that for decades, most states have put the burden on the drinking water system and its customers to pay for what took place upstream, said Cynthia Dougherty. The next use of the water is often considered unplanned potable reuse, which is not subject to stringent regulation at the point of discharge, noted James Crook, an environmental engineering consultant. An exception is California, where planned potable reuse projects are regulated both downstream and upstream with a variety of treatment, disposal, and monitoring requirements. Ironically, planned potable reuse is under severe restrictions, whereas unplanned potable reuse is often overlooked.

Another underregulated phenomenon is private wells. More than 40 million people in the United States get their drinking water from private wells, which tend to be threatened by the septic tanks that are usually present on the same rural property. This is a growing problem in light of demographic shifts to cities' outlying areas, because approximately 25 percent of new housing development depends on onsite treatment, said Susan Seacrest. This is probably one of the greatest public health threats facing the United States, but people do not want to think about it. Seacrest noted that a small but malfunctioning septic tank system can have significant microbiological loading in these locations.

MONITORING AS A RESEARCH NEED

Although research investigating linkages with health and research on technology were discussed, monitoring as a research need was noted by some panelists as a top priority. A number of agencies and research groups have been working in this area, but some panelists cautioned that it is unrealistic to assume that biosensors and biomonitoring would identify all potential contaminants and that source water protection and water conservation also would be necessary. Although research is going on in this area, noted Crook, it will be many years before meaningful results emerge. The research in this area has garnered more attention recently due to threats of bioterrorism and the desire to have rapid measures to address water contamination, noted Dougherty.

LAND-USE POLICY AND SOURCE WATER PROTECTION

During the course of the workshop, panelists characterized the identification of contaminants and the treatment of water as a cornerstone of ensuring safe drinking water. However, watershed protection and land-use policies also are important. For community systems a combination of land-use policies and treatment will probably be effective. Reckhow further noted that one technical difficulty is the reliable assessment of land-use controls, land-use restrictions, and activities in the watershed affecting the concentration of contaminants that are regulated in the Safe Drinking Water Act.

The leading research need for watershed protection, according to Reckhow, is the development of better predictive models. Streamflow models are considered reliable, and models of conservative contaminants (i.e., those that do not decay) such as salinity, chloride, and sediments also are very good. However, models of nonconservative contaminants (contaminants that transform) or biological organisms are far less reliable. Therefore, at present, we often cannot determine with a reasonable level of reliability how land-use controls and other activities in the watershed will affect drinking water quality. For this reason, better predictive mechanisms or models that link watershed actions to their drinking water effects should have high priority. The amount of money available for research in this area is limited and could become even more limited; therefore, we must try to look at this relationship in a more holistic way:

what might we do regarding source water that is going to have the maximum effect on protecting drinking water?

However, the research agenda that aims to produce models also must look at how to help local citizens understand and use them. It should look not only at what works and what the models are but at how they can be shared and what the best way is to implement them technologically and cost-efficiently. Science has to be understood and put into action by average people. We have to see the public as a real resource for this and we must respect and value its ability to be educated and be a force for positive change, especially on the local level, said Seacrest. Local people know their community better, care more about their community's future, and do more for their community. Groundwater, for example, must be protected at the local level because it is often a land-use issue—a local jurisdictional issue of what you can or cannot do on the land's surface.

KEEPING WATER IN THE LOCAL WATERSHED

Methods to achieve water capture at the community and watershed levels for purposes such as recharging groundwater are highly desirable. By contrast, the current way is to take a lot of raindrops and snowflakes—which should be going back into the hydrologic system where they fall and melt—shunt them miles away, and dump them in places where they shouldn't be dumped, at rates and temperatures and with all sorts of contaminants that are harmful.

It is still very difficult, Seacrest observed, to get our research institutes and others to help validate the claims that are made by advocates of this softer path—more natural system-based types of solutions. Funders are likewise reluctant, as evidenced by the relatively low priority given to such approaches by the International Monetary Fund (IMF) and the World Bank, as Peter Gleick noted earlier. Yet Gleick also suggested a way around this resistance: establishment of the principle that a soft-path ethic will not imply sacrifice. Water conservation, for example, should not necessarily be associated with a needed change in life-style. Keeping water in the watershed as locally as we can and letting it recharge or provide base flow to the local streams is something to strive for. There are many small-scale treatment processes that can treat wastewater successfully and put it back in the ground.

EDUCATION AND PUBLIC TRUST

Education is necessary if we are going to ensure public trust in the drinking water system. Education will be needed at all levels, including members of the public, local governments, and health care providers. Risk assessment has to be understood when individuals are concerned about contaminants in their drinking water, noted some panelists. It is difficult to predict which contaminants people will be concerned about and which they will ignore, noted Barker Hamill of the EPA Bureau of Safe Drinking Water. Other participants agreed and suggested that we should engage in regular discussions about the real issues that face our water supply and water quality and this discussion must include the public. Seacrest followed with the suggestion that resources have to be released for education. This is especially important for people who have a community-based system for water delivery or an individual system.

Abstracts

THE INTERFACE OF SCIENCE AND POLICY: ARE THE CURRENT POLICIES ABLE TO MEET CURRENT AND FUTURE CHALLENGES?

Fred Pontius

To address the question of whether current policies are able to meet current and future challenges, we must first consider how we got to where we are and the forces that have shaped current drinking water regulation. Drinking water regulations are set by the U.S. Environmental Protection Agency (EPA) under the Safe Drinking Water Act (SDWA), enacted in 1974. Since that time, the SDWA has undergone several reauthorizations, resulting in major changes in the way contaminants are regulated. In addition, the number of contaminants regulated has increase to 92—some are regulated with a maximum contaminant level (MCL) and some with a treatment technique, but all have a nonenforceable health goal, the maximum contaminant level goal (MCLG).

The scientific basis of and policy choices involved in regulating drinking water quality in the United States have changed as our experience has increased and as the SDWA has changed. In many respects, we are still adjusting as a society to recent policy shifts instituted by the SDWA amendments of 1996. The following key questions are discussed in this presentation, focusing on how science and policy choices have progressed over the years and whether current approaches can meet future challenges:

- How should contaminants be selected for regulation?
- How should MCLGs be established?
- How should MCLs be established?
- What constitutes the best science?
- What should be the role of source water protection?
- How can compliance be ensured?

Since enactment of the SDWA in 1974, great progress has been made in drinking water quality and regulation in the United States. It seems now that only the most difficult issues remain—protecting sensitive populations, achieving sustainable water systems, providing affordable drinking water for small systems, avoiding risk–risk trade-offs, and controlling emerging waterborne pathogens, to name a few. The need for creative thinking and innovation in drinking water science, policy, regulation, and legislation has never been greater.

**ARE RECENT ADVANCES IN SCIENCE AND TECHNOLOGY
ABLE TO MEET THE HEALTH CHALLENGES OF PROVIDING
SAFE DRINKING WATER?**

Jeffrey K. Griffiths

Narrowly, the provision of safe drinking water is dependent upon being able to (1) recognize the health risk of hazardous substances or microbes present in drinking water, (2) monitor drinking waters for the presence of these hazards, and (3) remove these hazards.

Challenges to providing safe drinking water include a diminishing supply of usable water, often most acute in areas with rapidly growing populations; an increasing need to reuse wastewaters that include sewage and industrial contaminants; and the demographic constraint of an aging population with increased relative susceptibility to drinking water contaminants. Specific populations, such as people with HIV infection or AIDS, are especially sensitive to emerging pathogens that were essentially not recognized in the pre-AIDS era. Predictions regarding climate change strongly suggest that less water will be available over time in multiple regions of North America. Industrial food production, via concentrated animal feeding operations (CAFOs), is increasingly cited as a source of animal pathogens that place humans at risk of zoonotic infection. Industrial production of novel chemical contaminants through

manufacturing also is increasing. These factors all conspire to increase the health risks that may be associated with drinking water consumption.

The study of modern health hazards in drinking water is a field in crisis, with an acute need for novel ways to study the population. Traditional epidemiological study methods are confounded by the mobility of the population and by difficulties in exposure assessment. It is hard to know what a person's integrated exposure is to drinking water contaminants that vary over time and space and how to assign a risk to a specific compound when a person is exposed to many of them. In addition, surveillance of the population is keyed to outbreaks of classical diseases, not to the detection of low-level or endemic emerging diseases. Fresh methods for monitoring the health of the community, such as those that look at population-wide outcomes and integrate exposures over time and space, are needed. Examples of such approaches are given here.

At the laboratory level, drinking water hazards are usually studied via a reductionist model. In this approach, individual compounds are studied in the absence of their actual context (e.g., as part of the chemical soup, however weak or strong) in which they are found. It seems increasingly unlikely that resources will be available to test every new compound that can be found in drinking water, to say nothing of the combinations that exist. Reflecting this reductionist model, the regulatory structure that exists regulates chemicals on a compound-by-compound basis. Research into the health hazards of compounds is often driven by regulatory interest, yet our scientific infrastructure is unlikely to be able to test the thousands of new compounds that are produced each year. New scientific approaches and paradigms are needed that recognize these realities.

Monitoring drinking water for chemical contaminants is difficult for a variety of reasons. For example, many compounds are present at such low concentrations that detection via standard methods is difficult. Furthermore, specific analytical techniques for the tens of thousands of chemical contaminants found in drinking water simply do not exist. Analytical techniques for the detection of pathogens in drinking water are primitive, relying almost solely on classical culture techniques. We now understand that conventional water treatment does not remove all risk of pathogen transmission. Chlorination-resistant organisms such as *Cryptosporidium* remain important risks for immunocompromised populations and for the general population when other measures such as filtration are weak or when they fail. Evolving technologies that involve water con-

centration, advanced chromatographic methods, and genomic recognition may prove extremely helpful.

Advanced treatment modalities such as ultraviolet irradiation, activated charcoal absorption, and membrane filtration of water may provide a broad, blanket form of water treatment to inactivate or remove infectious organisms and chemicals, but their costs are perceived as primarily affordable only for systems that serve large populations.

In sum, new scientific methods for the study of health risks in the population are needed, as are advanced monitoring and analytical methods. Water treatment technologies are not completely protective of the population and current advanced treatment methods are costly.

OVERVIEW OF THE TEXAS SOURCE WATER ASSESSMENT PROJECT

Greg Rogers

In November 1999, Texas received U.S. Environmental Protection Agency approval of its Source Water Assessment and Protection (SWAP) Program. This approval represents a major milestone in an ongoing cooperative effort between the Texas Commission on Environmental Quality (TCEQ) and the U.S. Geological Survey (USGS) to develop and implement a scientifically defensible methodology for assessing the susceptibility of Texas' public water supplies (PWS) to contamination.

Background

The 1996 amendments to the Safe Drinking Water Act require, for the first time, that each state prepare a source water assessment for all PWS. Previously, federal regulations focused on sampling and enforcement, with emphasis on the quality of delivered water. These amendments emphasize the importance of protecting the source water.

States are required to determine the drinking water source, the origin of contaminants monitored or potential contaminants to be monitored, and the intrinsic susceptibility of the source water. Under the amendments to the SWDA, states must create SWAP programs. The programs must include an individual source water assessment for each public water

system regulated by the state. These assessments will determine whether an individual drinking water source is susceptible to contamination.

During 1997–1999, TCEQ and USGS staff met as subject matter working groups to develop an approach to conducting Source Water Susceptibility Assessments (SWSAs) and a draft work plan. The draft work plan was then presented to and reviewed by various stakeholder and technical advisory groups. Comments and suggestions from these groups were considered and a final work plan was produced and presented to the EPA. After EPA approval, work formally began on the Texas SWAP project. The project has an expected completion date of September 2002. At that time, initial SWSAs of all Texas public water supplies should be complete.

Groundwater supplies can be considered susceptible if a possible source of contamination (PSOC) exists in the contributing area for the public supply well field or spring; the contaminant travel time to the well field or spring is short; and the soil zone, vadose zone, and aquifer/matrix materials are unlikely to adequately attenuate contaminants associated with the PSOC. In addition, particular types of land use or cover or within the contributing area may cause the supply to be deemed more susceptible to contamination. Finally, detection of various classes of constituents in water from wells in the vicinity of a public supply well may indicate susceptibility of the public supply well even though there may be no identifiable PSOC or land-use activity.

Surface water supplies are by nature susceptible to contamination from both point and nonpoint sources. The degree of susceptibility of a PWS to contamination can vary and is a function of the environmental setting, water and wastewater management practices, and land-use or cover within a water supply's contributing watershed area. For example, a PWS intake downstream from extensive urban development may be more susceptible to nonpoint source contamination than a PWS intake downstream from a forested, relatively undeveloped watershed. Surface water supplies also are susceptible to contamination from point sources, which may include permitted discharges, as well as accidental spills or other introduction of contaminants.

The development of a scientifically defensible methodology for assessing the susceptibility of Texas PWS to contamination, based on the most accurate, readily available hydrologic, hydrogeologic, point source, nonpoint source, and other natural resource and environmental data, will better enable the TCEQ SWAP staff to do the following:

- Focus its source water protection efforts on PWS that are more susceptible to contamination.
- Potentially reduce monitoring costs associated with ensuring safe drinking water.
- Assist the public in developing an improved understanding of the source of its water.
- Support the implementation of best management practices as needed to protect source waters.

Approach

For the Texas SWAP project, the susceptibility of a PWS is defined as the potential for the PWS to withdraw water containing a listed contaminant(s), at a concentration that would pose concern, through any of the following pathways: (1) direct injection or discharge; (2) soil; (3) geologic strata including faults, fissures, or other types of secondary porosity; (4) overland flow; (5) up-gradient water or streamflow; and (6) cracks in a well casing or intake pipe.

Susceptibility of a PWS to contamination is related to (1) the physical integrity of the well or intake and the pipe transmitting water from the well or intake, the treatment plant, and the distribution system; (2) the anthropogenic, physical, geologic, hydrologic, chemical, and biological characteristics of the source water area over which, or through which, water and contaminants will move to the supply point; (3) the type and number of PSOCs and land-use within the contributing area of a supply well, spring, or intake; and (4) the nature and quantity of contaminants that have been or potentially could be released within a contributing area, as well as measures in place to prevent such releases.

The Texas SWAP project consists of work in three subject areas: (1) assessment software and database structures, (2) groundwater assessments, and (3) surface water assessments. The groundwater and surface water assessment areas are further defined as sets of components, where each component deals with a specific problem domain of the SWSA.

Assessment Software and Database Structures

The objectives of this subject area are to design and develop database structures, assessment software, and technical documentation specifically to support staff in performance of SWSAs on TCEQ computers.

Surface water susceptibility assessments are technically complex activities dependent on relational database programming and spatial analysis techniques. Spatial analysis techniques are mostly available in commercial geographical information systems (GIS) software as lower-level computer functions. These functions are available as macros or “system commands,” but require specialized expertise to combine them into usable software components capable of performing the higher-level analyses required for SWSAs.

Decision rules governing the assessment of PWS susceptibility must be encoded and made available so that they may be applied to data derived from spatial analysis, local SWAP-specific databases, and data retrieved from TCEQ’s agency-wide databases. In some cases, these rules are simple yes or no tests; in other cases, a series of logic tests involving several relational database files must be applied. The software system developed will be easy to use by staff charged with assessing PWS and will be compatible with TCEQ’s existing databases. Specialized training in GIS technology will not be required. Because of the volume and variety of required data and the level of technical detail of SWSAs, the staff requires access to software documentation and help files, metadata, bibliographic, and other supplementary information. The system being developed will make these data files and references available to the analyst at all times.

To complete the large number of assessments (more than 17,000) required, the software must be capable of supporting unattended (batch) processing of SWSAs. As larger-scale data sets are produced for Texas, SWSAs will be repeated—hence the ongoing requirement for unattended processing. In cases where a single assessment (a new PWS) or a small number of assessments are to be completed, an interactive version is desired. It is anticipated that as SWSAs become more technically complex and larger-scale data sets come online, assessments will require interactive rather than batch processing.

Software development efforts include (1) requirements analysis, design, development, testing, and documentation of database structures and assessment software; (2) a data object model defining overall database structure, data tables, data fields within tables, and data–entity relations including a data dictionary; (3) user interface software for display of GIS coverage, database query, hard-copy output, or report generation; (4) spatial analysis software for delineation of contributing areas, and calculation or determination of weighted variables, characteristics, and threshold values; (5) software to assist the user in applying appropriate

decision rules for determining susceptibility within SWSA components and determining overall susceptibility; and (6) a graphical user interface to provide access to databases, assessment software, online help, and documentation and support for interactive or batch processing.

Groundwater Assessments

The groundwater susceptibility assessment subject area consists of seven components, each addressing a specific problem domain. The primary focus of this subject area is the design and development of databases and software to enable SWSAs on PWS with groundwater as the primary source of water.

Identification component It is necessary to identify which aquifer a well derives its water from, since all subsequent determinations in SWSAs are based on aquifer type and hydrologic characteristics.

In Texas, 9 major and 20 minor aquifers have been mapped. These 29 aquifers have been subdivided and assigned some 450 aquifer codes, each having its own geologic, hydrologic, and water quality characteristics. These aquifer codes have been developed for several uses, including regulation of public drinking water; however, the 29 major and minor aquifers do not provide sufficient detail for the purposes of SWAP. Alternatively, data requirements for 450 aquifer codes are beyond the scope of this component. Thus, agreement was reached between various stakeholders, including representatives of TCEQ, the Texas Water Development Board (TWDB), and USGS, regarding a designation of about 45 aquifer codes that provide adequate detail.

Texas aquifers, for the purposes of SWAP, are designated as one of five major aquifer categories. Four of the categories are unconfined isotropic aquifers, confined isotropic aquifers, alluvial aquifers along major rivers, and anisotropic karst aquifers. Additionally, there are some public groundwater supplies in Texas that do not obtain water from the mapped major and minor aquifer systems or that obtain water where an aquifer determination cannot be made. Thus, a fifth aquifer category of “unknown” is required for susceptibility assessment purposes. Separate approaches have been developed for the five aquifer categories, because of their hydrogeologic characteristics.

Contributing area delineation component SWSAs require that the contributing area to each PWS well or spring be determined so that PSOCs

occurring within may be identified and assessed as to their potential effect on water quality.

Delineation of the contributing area for water to enter the groundwater system for a specific well field or spring is complicated by (1) complex geologic structure, (2) groundwater–surface water interaction, (3) heterogeneous aquifer matrix material resulting from the depositional environment of the aquifer, and (4) limited site-specific aquifer information.

Although there are several methods for determination of contributing areas of a PWS well or spring, flow-net analysis was chosen because of the regional scale of the problem, as well as knowledge of and assumptions made about the hydrogeologic properties of Texas aquifers. Using specially developed GIS software, the portion of the flow net that defines the contributing area for the water supply well or spring will be identified and a determination of time of travel to the well for all aquifer categories will be made, with the exception of the Edwards aquifer, where data from the USGS flow path investigations will be used.

Using this approach, the characterization of the aquifer is such that only the horizontal movement of water to the water table is approximated, not the vertical movement. The assumption is that the contributing area to a well in an unconfined system is the area directly above the flow paths for a specified end time (2, 5, 10, 20, and 100 years). In a confined system, the contributing area is that area within specified end times or terminating in the outcrop of the aquifer for similarly specified end times.

Tasks associated with this component are focused on developing data sets and software for delineation of contributing areas to PWS wells or springs that derive their water from the five categories of aquifers. GIS coverage produced under this component includes (1) time of travel and contributing area for wells or springs in confined or unconfined isotropic aquifers and alluvial aquifers, (2) contributing area for wells or springs in the Edwards aquifer, and (3) contributing area for wells or springs in unknown aquifers.

Nonpoint source component This component will involve a statewide investigation to develop statistical relations between known occurrences of nonpoint source contaminants in groundwater and the natural and anthropogenic factors or activities (referred to as environmental variables) within the capture zone contributing the water. To supplement existing TCEQ and USGS contaminant occurrence databases, 160 PWS wells

were sampled during 1999–2000. The PWS wells selected for sampling are located primarily in shallow, unconfined aquifers (those most susceptible to nonpoint source contamination) and have characteristics representative of a range of environmental variables that may influence source water susceptibility. Samples are collected using specialized, low-level detection sampling procedures developed by the USGS and analyzed for selected soluble pesticides, volatile organic compounds (VOCs) including methyl tert-butyl ether (MTBE), and nitrates. Environmental variable databases also are being compiled (to the extent that data are available) to support the development of statistical relations. These statewide databases of potential explanatory variables are wide ranging and include land-use (percentage urban, population density, animal densities or CAFOs, agricultural crop acreage, oil and gas production), selected natural factors (soil properties and hydrologic characteristics), and urban and agricultural pesticide and nutrient use. TCEQ will develop threshold values from the statistical relations.

Point source component A primary step in assessing the susceptibility of a groundwater supply to contamination is locating PSOCs within the contributing area of a supply. Selected categories of PSOCs that may contribute contaminants to the PWS well or spring are underground storage tanks; operative and closed solid and hazardous waste management units, including landfills, surface impoundments, and waste piles; uncontrolled hazardous waste disposal and spill sites, including Superfund sites; waste injection wells, including the family of Class V wells; and septic systems.

Texas state databases hold records for an estimated 65,000 known PSOCs. Although location information for the majority of these sites is available from the databases, this information is not accessible using the spatial analysis software in the various SWAP components. Approximately 10,000 PSOCs have no digital location information (latitude–longitude) as is required. The information for these sites may be available from a physical review of paper files maintained by TCEQ’s various PSOC programs. In some cases, PSOCs may have been located on USGS topographic maps; in other cases, only paper engineering reports, site drawings, or field sketches may exist. In still other cases, only street address information is available in the file.

A large amount of work is going on to obtain accurate location data for PSOCs. Interviews with pertinent TCEQ staff who manage PSOC programs were conducted to determine data type, attributes, locations,

quality, availability, and documentation. A comprehensive flowchart and list of interview questions to facilitate this process were developed and followed. For each PSOC for which location data are required, the paper file is physically pulled, reviewed, and pertinent information extracted, to allow the PSOC, if possible, to be located on a USGS topographic map or equivalent. Supplemental maps or commercial databases with address or location information will be required to locate some PSOCs.

This information is then put into a GIS database that will provide a variety of information on PSOCs, including the TCEQ program that collects and manages the PSOC data, the source material for the data, descriptions of data quality, and minimal accuracy standards (or needs) for PSOC locations. The database will be linked to the list of regulated contaminants (and contaminant groups) and to Standard Industrial Codes. A relational database providing technical data on the environmental behavior and fate of contaminants will be developed to assist evaluation of a potential contaminant or group of contaminants associated with the PSOC. The output from spatial analyses and database software of this component is a list of PSOCs within the contributing area of the PWS. The software also will provide a list of contaminants and quantities (when available) associated with the PSOC that are analyzed as part of subsequent components.

Contaminant occurrence component Some aquifers have naturally occurring contaminants that render the water less desirable for human consumption. Thus, an analysis, both spatial and temporal, of existing groundwater and PWS entry point monitoring data is needed to determine whether the measured occurrence of a contaminant in water from an aquifer is caused by natural or anthropogenic conditions. This analysis also may uncover sources of contamination caused by breaches of the confining unit for a confined aquifer. Several existing databases contain groundwater quality data useful for this analysis. Using spatial analysis techniques, water quality sampling sites will be identified within a 1-mile search radius around each PWS well and spring. If contaminants are detected within this area, the PWS would be assessed as being susceptible to either anthropogenic or naturally occurring contamination. These data will be used to identify sites with contaminant occurrences exceeding designated thresholds for specific constituents within a 1-mile search radius of the PWS well or spring.

Attenuation of contaminants Contaminants released from a point source, or from the land surface, that enter aquifers as solutes in groundwater undergo physical, chemical, and biochemical processes that lower their concentrations in the groundwater. The concentration of a contaminant in groundwater and its time of arrival at the point of exposure also are determined by the physical, chemical, and biochemical processes that may attenuate (lower) its concentration. Conservative behavior could mean that a contaminant might exceed the EPA MCL within a 20-year time of travel period of consideration at a PWS. Nonconservative behavior could mean that a contaminant might be attenuated in the soil, vadose zone, or aquifer matrix, depending on its specific properties, perhaps never arriving at the PWS or arriving at concentrations below levels of concern. Thus, it is important to include considerations of fate and transport based on behavioral data for each contaminant, along with physical properties of the soil, unsaturated (vadose) zones, and aquifer matrices.

Although time of travel is the most critical element in the evaluation of PWS susceptibility, the attenuation property of the soils, vadose zone, and aquifer matrix in the contributing area of the well or spring will be considered in the assessment. Some of the most important properties of the soil zone affecting contaminant fate and transport are permeability, thickness, and total organic material content. Additionally, the greater the depth to water, the longer the travel time will be to the aquifer through the vadose zone. The rock type of some aquifers also may inhibit the transport of some contaminants. A decision matrix will be developed for these properties to assess the generalized intrinsic capability of these zones to attenuate contaminants. The output of software using the decision matrix developed for this component will be a determination of whether the contaminant in question would be attenuated before affecting the PWS.

Susceptibility summary determination component This component will determine the cumulative susceptibility of the PWS to each listed contaminant or contaminant group, as contributed by point and nonpoint sources. The susceptibility determination will be automated using software to populate a matrix-type table with unique codes describing the PWS, surface and groundwater hydrologic setting, PSOC(s) and their contaminant(s), intrinsic capability to attenuate contaminants, and so on. The matrix will include every possible combination of codes with a predefined susceptibility determination. The software will compare the codes generated for each water system against the decision rules and ap-

ply a summary determination of susceptibility. This complex and extensive information will be simplified into a form easily comprehended, with a detailed report prepared for the water purveyor and a summary report produced for the public. A similar reporting method has been used for the last several years by the TCEQ Vulnerability Assessment Program and provides a simple, objective, rapid, and automated evaluation.

Surfacewater Assessments

The surfacewater susceptibility assessment subject area consists of seven components, each addressing different problem domains. The primary focus of this subject area is the design and development of databases and software to enable SWSAs on PWS with surfacewater as the primary source of water.

Delineation component The contributing watershed area must be determined for surface water intakes or outlets of PWS reservoirs so that PSOCs within the contributing watershed may be identified and evaluated. Land-use types within the contributing watershed must be determined to assess their potential nonpoint source effect on the water supply. Characteristics such as rainfall, runoff, and reservoir storage must be obtained for the contributing watershed to assess the intrinsic susceptibility of each surface water supply. Six types of watersheds are used in SWSA:

1. contributing watershed to the intake (delineated at the PWS reservoir outlet or at the mapped location of the intake on the stream);
2. contributing watershed to a stream, reservoir, municipal stormwater, or other water quality monitoring site;
3. contributing watershed for all non-PWS reservoirs with normal storage capacity greater than 1,000 acre-feet and located within the contributing area of the PWS intake;
4. truncated watershed (as required) for the area within the contributing watershed to the intake but excluding any contributing watersheds of non-PWS reservoirs with normal storage capacity greater than 1,000 acre-feet;
5. area of primary influence, defined as the area within 1,000 feet of a reservoir boundary and for all streams discharging directly to the reservoir the area within 1,000 feet of the center of the stream channel of an estimated 2-hour travel-time stream reach immediately upstream from

the reservoir; for intakes on streams, the area of primary influence is the area within 1,000 feet of the estimated 2-hour travel-time stream reach upstream from the intake; and

6. multijurisdictional area, defined as a contributing watershed area that is outside the state boundary, such as the Red River and the Rio Grande.

Contributing watershed delineations are required for about 500 surface water supply intakes of which about 176 are unique (multiple intakes in various reservoirs). Contributing areas also may be required for an estimated 90 additional reservoirs located within the contributing areas of PWS reservoirs. Finally, areas of primary influence for all surface PWS must be delineated.

Using specially developed software, watershed delineations are generated and then adjusted manually as necessary. Statewide coverage used in the watershed delineation process and created specifically or modified for use in this project includes

- digital elevation models (a new statewide database, developed at 60-meter resolution by the USGS for SWAP);
- flow direction and flow accumulation data sets;
- hydrograph (streams and reservoir boundaries); and
- intrinsic characteristics component.

Surface water supplies are all susceptible to contamination to some degree because contaminants released at the land surface can potentially reach supplies in relatively short time. Factors that can affect the relative magnitude of susceptibility are geology, soil characteristics, vegetative cover, amount of runoff, and attenuation of contaminants in watersheds. Eroded soil may carry, absorbed on the surface of sediment particles organic chemicals, pesticides, nutrients, and heavy metals. The dilution capacity and contaminant degradation capability of a stream or reservoir affect the fate, transport, and degradation of contaminants. Finally, the slope of the land is a major control on the time of travel of contaminants in runoff. Assessment of each of these factors would require very detailed, site-specific data that are not readily available in many cases; if the data were available, adding each of these components would result in the susceptibility assessment tools being too complex for source water assessment purposes. Instead, the following four broad measures will be used to assess the intrinsic susceptibility of a PWS:

1. intrinsic susceptibility associated with mean annual and mean seasonal surface runoff;
2. intrinsic susceptibility associated with soil credibility for contributing watersheds of water supply intakes;
3. potential effects of reservoirs within a watershed on concentration of contaminants; and
4. intrinsic susceptibility associated with time of travel.

Major efforts in support of this component are focused on the development of predictive equations for mean annual and mean seasonal runoff based on watershed characteristics; development of GIS databases for mean annual and mean seasonal precipitation; and calculation of the ratio of annual and seasonal runoff to annual and seasonal precipitation. Index values will be used to define susceptibility of the PWS caused by runoff.

Development of a soil credibility database also is required for this component. An index of high-, medium-, and low-erodibility soils is being developed that will be used to determine the susceptibility of the PWS to contaminants associated with eroded soils. Higher soil erodibility values indicate greater susceptibility; lower soil erodibility values indicate less susceptibility.

The potential effect of reservoirs in the watershed will be assessed by analysis of the ratio of total storage in the watershed to annual runoff in the watershed. High index values indicate less susceptibility at the intake because of reservoir storage (a beneficial effect resulting from dilution); low index values indicate increased susceptibility.

To assess a watershed's intrinsic susceptibility associated with time of travel, the ratio of the area of the contributing watershed to the basin slope will be calculated. High size-slope ratios indicate longer time of travel and thus less susceptibility; low ratios indicate shorter time of travel and thus increased susceptibility.

Nonpoint source component This component will involve a statewide investigation to develop statistical relations between known occurrences of nonpoint source contaminants in surface water and natural and anthropogenic factors or activities (environmental variables) within the watershed. To supplement existing TCEQ, Clean Rivers Program, and USGS contaminant occurrence databases, 48 PWS reservoirs were sampled during 1999–2000. The PWS reservoirs selected for sampling have watersheds representative of the various hydrologic conditions and land-uses in Texas. Samples are collected using specialized, low-level detection

sampling procedures developed by the USGS and analyzed for selected soluble pesticides and VOCs (including MTBE). As stated in the groundwater component, environmental variable databases to support the development of statistical relations also are being compiled that include land-use (percentage urban, population density, animal densities or CAFOs, agricultural crop acreage, oil and gas production); selected natural factors (soil properties and hydrologic characteristics); and urban and agricultural pesticide and nutrient use. TCEQ will develop threshold values from the statistical relations.

Point source component The objective of this component is to assess the susceptibility of surface water supplies to point source discharges during low-flow conditions. Although point source discharges may be included in the environmental setting variables used statistically, the existing water quality data sets may not adequately represent low-flow conditions when point sources have their greatest influence on the water quality of the receiving water body. Therefore, theoretical concentrations of point source-associated contaminants at low-streamflow and low-flow reservoir storage conditions will be calculated on the basis of permitted releases of contaminants from point source discharges in the contributing watershed of the surface water intake or supply reservoir. A ratio of the total permitted releases of the contaminant to reservoir storage or to mean annual streamflow will be developed. Higher ratios indicate greater susceptibility.

Contaminant occurrence component Some watersheds have naturally occurring contaminants that render the water less desirable for human consumption. Thus, an analysis, both spatial and temporal, of existing surface water quality and PWS point of entry (POE) monitoring data is needed to determine whether the occurrence of a contaminant in water is caused by natural conditions in the watershed. Several existing databases contain surface water quality data useful for this analysis, such as TCEQ surface water quality and entrapment databases and USGS National Water Information System databases. Using spatial analysis techniques, these data will be identified within each watershed containing a PWS intake or reservoir. If naturally occurring contaminants are detected within a watershed, the contributing watershed will be assessed as susceptible to contamination from such contaminants.

Contaminant detections also serve as a confirmation check of the methodology for assessing the degree of susceptibility of source water to

contamination. Stream, reservoir, and entrypoint monitoring data will be used to verify assessment decisions. If a surface water source is determined to have low susceptibility to a particular contaminant, then monitoring data should not reveal detections. If monitoring data reveal detections, the assessment model must be reevaluated. If a surface water source is determined to have high susceptibility, data may or may not support the assessment. The lack of detection may only mean that the stream, reservoir, and PWS or POE monitoring data were not collected at the appropriate “hydrologic” time (e.g., during or just after a runoff event, during base flow conditions).

Area-of-primary-influence component The proximity of a surface water intake to a point source discharge, potentially adverse land-use, major transportation corridor, or pipeline can result in the source water being susceptible to contamination. The relatively short time of travel of a chemical spill, continuous release, or runoff to the intake minimizes the opportunity for reducing a contaminant concentration or converting or degrading a contaminant to a less hazardous form.

The approach will consist of compilation and/or creation of GIS data sets as necessary to support area-of-primary-influence (API) assessments using software developed under a separate task. For intakes in reservoirs, an API will initially be defined as the area within 1,000 feet of a reservoir boundary and for all streams discharging directly to the reservoir the area within 1,000 feet of the center of the stream channel of the estimated 2-hour travel-time stream reach immediately upstream from the reservoir. For intakes on streams, the API is the area within 1,000 feet of the estimated 2-hour travel-time stream reach upstream from the intake. On an as-needed basis, the API will be tailored to the specific PWS by the incorporation of ancillary data sets such as floodprone areas and/or actual time of travel where flow characteristics are readily available.

Within the API, all PSOCs, including permitted point sources and marinas, land-uses, transportation corridors, pipelines, or electrical transmission lines, will be identified along with their associated contaminant groups. A qualitative determination of susceptibility (decreased susceptibility to increased susceptibility) will be assigned on the basis of presence of PSOCs, potential for releases or spills of contaminants, and contaminants associated with each specific PSOC in the API. The susceptibility determination will be guided by the number of PSOC sites, the total area dedicated to activities known to generate contaminants, and the

contaminants and amounts (if available) potentially generated by various activities within the API.

Susceptibility summary determination component As in ground-water susceptibility assessments, this component will determine the cumulative susceptibility of the PWS to each listed contaminant or contaminant group, as contributed by point and nonpoint sources. The susceptibility determination will be automated using software to populate a matrix-type table with unique codes describing the intake, hydrologic setting, PSOC(s) and their contaminant(s), intrinsic susceptibility, and so forth. This complex and extensive information will be simplified into a form easily comprehended. A detailed report and a summary report for the PWS will be produced.

LAND-USE PLANNING: A CONCERN FOR SOURCE WATER PROTECTION?

Douglas “Dusty” Hall¹

Centuries-old “conventional wisdom” suggests that the outhouse should not be located near the drinking water well. That said, if this is centuries-old conventional wisdom, then why do so many new examples of development create risks to drinking water?

Comprehensive land-use planning and complementary authority are critical needs for source water and public health protection. The City of Dayton, Ohio, has implemented an extraordinary set of measures in response to threats to its drinking water resulting from inadequate, historical land-use planning. Societal changes, such as the migration of people from urban centers, are driving development patterns that are creating new risks to public health in areas where planning or authority may be insufficient.

¹The Miami Conservancy District (MCD) is a political subdivision of the State of Ohio and steward of the Great Miami River watershed in west central and southwestern Ohio. The watershed is rich in water resources and serves as home to about 1.5 million people. While its core mission is flood protection, MCD has integrated program efforts that include groundwater and source water protection, surface water quantity and quality monitoring, and the enhancement of river corridors within the watershed.

Land-Use Planning—An Urban Exposure

The City of Dayton, along with many other communities, has long benefited from the Great Miami River watershed's buried valley aquifer system. The city taps this resource to provide potable water to about 440,000 people in the Dayton area. The aquifer is readily recharged by water from the watershed's rivers and streams. Unfortunately, other activities on the land may adversely affect the aquifer.

For more than a century, Dayton's manufacturing economy flourished above the aquifer. In 1926, Dayton's first land-use plan promoted industrial growth above the aquifer. As Dayton and its water needs grew, so did potential threats to the safety of the drinking water supply.

In the 1980s, citizens' concerns for the safety of drinking water prompted the city to initiate a community-based effort to provide for the long-term safety of Dayton's source water. The comprehensive well field protection program that evolved includes a balance of regulatory strategies and incentives. A zoning overlay district was established to prevent new incompatible development. Financial incentives were developed to address the hazards posed by existing uses. Groundwater monitoring, enhanced emergency response, and educational efforts rounded out the award-winning program.

The Changing Landscape

In the 1970s, the collective population of Ohio's large urban centers peaked. Since 1970, townships near the urban centers have experienced high growth rates and large cities have lost population. The greatest population growth has occurred in an area extending from 10 to 20 miles outside urban centers (Clark et al., 2003).

Land-Use Planning—A Rural Exposure

The urbanization of formerly rural areas of Ohio has outpaced the advance of public water and sewer infrastructure. The Ohio Department of Health (ODH) projects that more than one in four new houses constructed in these areas will be built with private household sewage treatment systems (HSTSs). The ODH estimates that there are currently one million HSTSs, only about 8 percent of which are subject to oversight or

inspection. The ODH also estimates that about 25 percent of the systems are failing, with up to 900,000 gallons of sewage discharged per day.

As described above, Ohio's growth has occurred primarily in townships. Ohio is a "home-rule" state, giving municipalities significant powers of self-governance while counties and townships may act only as specified by Ohio law. In Ohio, there is no specific authority for townships to create or adopt a comprehensive plan (Clark et al., 2003). In some instances, health district staff are de facto planners for townships by their actions to approve or disapprove proposed HSTSSs.

Bridging the Gap

The case for comprehensive land-use planning that addresses the sustainability of water resources is abundantly supported by history. What is less clear however is the evolving public health risk associated with the development patterns of the last three decades. Is there a public health justification for supporting sustainable growth initiatives, increased comprehensive planning, and complementary authority to implement the plans? The answer to this question cannot come soon enough.

IMPACTS OF NONPOINT SOURCE POLLUTION ON DRINKING WATER AND HUMAN HEALTH

Thomas W. Christensen

According to the U.S. Environmental Protection Agency Inventory of Water Quality (USEPA, 2000), nonpoint source pollution from agricultural lands is among the leading sources of impairment of our nation's waterways. Absent the application and maintenance of science-based best management practices (BMPs), runoff and leaching from agricultural lands can affect both surface and groundwater sources of drinking water. Excess quantities of nutrients and pesticides are among the primary pollutants and each of these contaminants can pose potential risks to human health. The U.S. Department of Agriculture (USDA), through research, technology transfer, education and outreach, and technical and financial assistance programs for conservation, is working diligently to help farmers and ranchers minimize these risks and reduce the effects of

nonpoint source pollution on drinking water sources. Today's enhanced partnerships and increased conservation authorities and funding, coupled with the USDA's experience in helping farmers and ranchers with practical on-the-ground solutions to address water quality concerns are exciting and encouraging developments that should further accelerate water quality improvements in agricultural settings.

Recognized agricultural contributions to drinking water pollution have traditionally included sediment, nutrients, and pesticides. Overenrichment of nutrients, particularly nitrogen and phosphorus, is a leading surface and groundwater pollutant. Nitrates have been implicated in drinking water contamination in some rural areas. Exposure to nitrate is chiefly a concern for those whose source water is groundwater, because groundwater generally has higher nitrate concentrations than surface water.

Although agriculturally induced soil erosion has declined significantly (nearly 40 percent) over the past 20 years, sediment remains the largest contaminant of surface water by weight and volume. Accelerated sedimentation reduces the useful life of reservoirs, while suspended sediment increases the cost of water treatment.

A diverse array of pesticides is applied to agricultural crops across the country. If not applied according to EPA label requirements and in combination with sound conservation measures, these pesticides can pose a potential risk to human health. To date, however, studies by the USGS generally have found low levels of pesticides in most of the waterways surveyed in agricultural basins. Moreover, a 1992 EPA survey of drinking water wells found that pesticide concentrations in groundwater rarely exceeded legal maximum exposure limits. Nonetheless, the appropriate use of pesticides in agriculture through practices such as integrated pest management remains a high priority for the USDA and the agricultural conservation community.

In addition to the commonly cited contaminants in agricultural settings, pathogens and pharmaceuticals have emerged in recent years as potential water quality concerns. Pathogens may enter drinking water supplies from agricultural feedlots and fields fertilized with animal manure where conservation management either is not practiced or is not practiced adequately. For instance, there is concern that pharmaceuticals—primarily antibiotics and hormones fed to livestock and poultry—may enter waterways as a component of animal manure and litter runoff, especially when manure and litter are not applied in accordance with a comprehensive nutrient management plan consistent with the

USDA Natural Resources Conservation Service's (NRCS) (USDA, 2000) technical guidance.

Although much work remains to be done to restore and protect the nation's waters, the United States has made significant progress in cleaning up polluted waters, especially over the past few decades. Many farmers and ranchers, with assistance from NRCS, state conservation agencies, local conservation districts, and others, have been active stewards of soil, water, and other natural resources for decades. Based on 70 years of experience, lessons learned, and success stories to date, the USDA remains a proponent of the voluntary, locally led, incentive-based approach as the principal means to help agricultural producers reduce the environmental consequences of production. Environmental regulation has a proper role, as evidenced by EPA's Concentrated Animal Feeding Operations Rule for the largest animal feeding operations, but it is largely a complementary role—providing the vehicle for regulatory authorities to address the actions of “bad actors” and/or set expectations for sensitive areas subject to the greatest environmental risk.

Conservation technical assistance programs are the primary tools used by NRCS to improve water quality in agricultural settings. NRCS field personnel, in cooperation with other public and private technical service providers, supply technical assistance directly to farmers and ranchers to help them meet their goals for natural resource stewardship. USDA's conservation programs, such as the Environmental Quality Incentives Program (EQIP), are used by many agricultural producers for the technical and financial assistance tools to help them comply with federal, state, and local regulations. Conservation practices, such as crop residue management, nutrient management, integrated pest management, grassed waterways, field borders, and buffer strips, combined into conservation systems, are proven to keep soil and nutrients in place and thereby minimize the risk of contaminated runoff leaving farm fields.

NRCS does not work alone in its efforts to reduce the agricultural contributions to drinking water contamination. The agency's relationship to its core conservation partners (including local conservation districts and state conservation agencies) ensures the efficient delivery of technical and financial assistance through locally led processes. Other USDA agencies, such as the Agricultural Research Service and the Cooperative States Research, Education, and Extension Service (CSREES), perform equally valuable complementary functions, including conservation research, education, and outreach. Additional federal partners include EPA

and the U.S. Department of the Interior, where public and private land conservation and management issues interface.

Located in the rural Potomac headwaters area in West Virginia, the North Fork Project is an example of a successful multiagency watershed partnership approach to solve a water quality problem on a scenic, high-quality stream. The Potomac River supplies drinking water to millions of people in the Washington, D.C., metropolitan region. The North Fork of the Potomac was plagued by elevated levels of fecal coliform bacteria, due primarily to polluted runoff from intensive animal agricultural operations along the waterway. As a result of the implementation of numerous BMPs funded under several federal and state water quality programs, the water quality of the North Fork of the South Branch of the Potomac River has improved to such an extent that the stream no longer exceeds criteria for the listing of impaired or polluted water bodies in West Virginia (Federal Clean Water Act, Section 303(d)). This success was made possible through funding from the USDA, the EPA, and the State of West Virginia, along with farmers' individual contributions of time, knowledge, and resources. Numerous other partners at the state and local levels helped produce an 85 percent voluntary landowner participation rate in this exemplary watershed project.

The North Fork Project and similar successes across the nation have elucidated the key ingredients for water quality improvement in impaired watersheds. Management of land and water resources on a watershed basis, enhanced partnerships and collaboration, and access to focused and accurate water quality information are critical components in mitigating nonpoint source pollution in agricultural watersheds. Increasing BMP adoption by landowners is a goal of NRCS and its partners. Achieving this goal will require the establishment of better links between best management practices and water quality improvements, better economic information on BMPs, and a greater awareness of social and cultural considerations to improve the effectiveness of outreach efforts to landowners.

Additional research needs exist beyond the scope of BMPs. There is a need to characterize the nature, extent of occurrence, behavior, transport, and fate of emerging contaminants in the environment such as pharmaceuticals, hormones, endocrine disrupters, and environmentally robust and antibiotic-resistant pathogens. Development of economical, community-based solutions is necessary to address watershed-scale problems. Improved monitoring and modeling techniques and technologies

are needed to provide decision makers with targeted, accurate water quality information.

The USDA and EPA are working together to address these research needs. The enhanced federal partnership between USDA and EPA in recent years has led to more effective interactions on significant water quality activities. Collaboration on the Concentrated Animal Feeding Operation Rule, the Chesapeake Bay and Mississippi River basin nutrient over enrichment challenges, and source water protection activities provide an impetus for additional successes in the future. An important ongoing collaboration between the two agencies is an effort to promote the adoption of water quality trading projects in impaired watersheds. The USDA supports EPA's voluntary Water Quality Trading Policy (USEPA, 2003) and is currently developing its own environmental credit trading policy that will describe key principles and policies, as well as identify agency roles and responsibilities.

In 2002, Congress provided the USDA with powerful tools to address water quality concerns through new authorities and increased funding in the Farm Bill. An example of the significant increase in funding authorized by Congress is for EQIP, which in federal fiscal year 2004 is authorized at \$1 billion. NRCS is proceeding rapidly with program implementation in order to deliver this increased funding to more producers to facilitate more widespread on-the-ground conservation.

The USDA is committed to improving water quality and reducing the effects of agricultural nonpoint source pollution on drinking water and human health. Providing incentives for good stewardship, supporting research and innovative science-based technologies, expanding and enhancing partnerships, and informing and supporting locally led decision making are the cornerstones of this commitment.

NUTRIENT LOADING: CRITICAL LINK IN THE CHAIN

Kenneth H. Reckhow

The nutrients in natural waters of greatest concern for human and ecological health are nitrogen and phosphorus. In the United States nitrate nitrogen is regulated in drinking water standards for human health concerns and nitrogen and phosphorus criteria have been proposed for the control of eutrophication in surface waters. Nitrate has a direct human health effect in infants; excessive nitrogen and phosphorus loading

to surface waters has an indirect effect through algal growths that may produce toxins or serve as trihalomethane precursors. These effects are discussed briefly.

The primary focus of this presentation is on nutrient loading; that is, the particularly concerned about the input of nitrogen and phosphorus to surface and groundwaters, with emphasis on the sources, assessment, and management.

Current scientific knowledge is strongest concerning the recognition of important sources of nitrogen and phosphorus. In the absence of human activity (or “background”), there are typically low-level contributions of nutrients to surface and groundwater from the atmosphere, decaying plant material, and erosion and bedrock weathering. This contribution is natural, and while it can be modified by human activities, it occurs with or without human intervention. Anthropogenic inputs of nitrogen and phosphorus to surface and groundwaters may be far greater in magnitude than natural inputs; the most significant anthropogenic sources are wastewater treatment plants, urban runoff, agricultural activity, and fossil fuel burning.

Fortunately, we know the cycles of nitrogen and phosphorus; thus, from a conceptual standpoint, we understand the set of possible outcomes once nitrogen and phosphorus are introduced into the environment. In other words, we know the transformations that nitrogen and phosphorus undergo and we can characterize the reaction rates for these transformations of nutrients under controlled (i.e., laboratory) conditions.

The picture becomes considerably less certain, however, when applying this general “laboratory” knowledge of nutrient sources and transformations to assess the effect of nitrogen or phosphorus loading in a specific aquatic environment. The natural environment is complex and highly variable; thus, our ability to predict the response of an aquatic system to nutrient loading will always be restricted by our ability to understand and characterize this complexity and variability. As a consequence, predictions of the effect of nitrogen and phosphorus loading to surface and groundwater are not very accurate in many situations. A case study addressing the effect of nitrogen loading to the Neuse River in North Carolina provides an example of the difficulties in (1) estimating nutrient loading, (2) assessing the effect of that loading, and (3) determining appropriate management strategies.

STATUS AND TRENDS IN ATMOSPHERIC DEPOSITION OF NITROGEN AND MERCURY IN THE UNITED STATES

Mark A. Nilles

Approximately 23 million tons of nitrogen oxides, 5 million tons of ammonia, and 158 tons of mercury from anthropogenic sources are estimated to be emitted annually to the atmosphere in the United States (USEPA, 1998, 2003). Current assessments identify fossil fuel combustion as the primary source of nitrogen oxide and anthropogenic mercury emissions, while livestock agriculture and fertilizer application are the primary sources of ammonia emissions.

Since 1978 a cooperative national monitoring effort has tracked the status and changes in wet deposition in the United States. The National Atmospheric Deposition Program (NADP) is cooperatively supported by more than 100 organizations, including 8 federal agencies, state and local agencies, universities, and private industries who pool resources to support centralized program management, site operation and maintenance, chemical analysis, data management, and quality assurance programs. NADP currently supports 250 sites nationwide to monitor acidity, nutrients, and base locations. In 1996, NADP initiated the Mercury Deposition Network (MDN), which now comprises 100 sites to monitor total mercury and methyl in precipitation.

Deposition of atmospheric nitrogen compounds to aquatic and terrestrial ecosystems can range from a negligible contribution to the predominant source of overall nitrogen inputs. NADP data indicate that the concentration and deposition of nitrate in precipitation are greatest in and downwind of the industrialized Midwest and Northeast regions of the United States, while for ammonium, the greatest flux occurs in and downwind of the primary plant and animal agricultural regions of the Midwest. The spatial distribution of mercury wet deposition in the United States exhibits greater complexity, possibly due to the integration of large-scale regional and global atmospheric processes with local emission and deposition processes (NADP, 2002) (see Figure A.1).

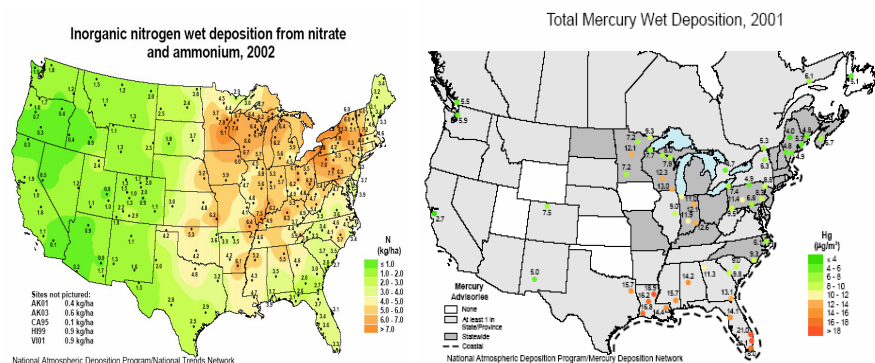


FIGURE A.1 Wet deposition of nitrogen compounds and mercury in the United States.
SOURCE: National Atmospheric Deposition Program, National Trends Network (2002).

Trends in wet deposition of oxidized and reduced forms of nitrogen have not followed the well-documented declines in sulfate deposition in the United States. Monthly data from 149 sites in the NADP National Trends Network were evaluated for trends over the period 1985–2001 using a parametric model to remove the influence of interannual variations in precipitation amount, followed by a nonparametric test for detection of monotonic trends (Nilles and Conley, 2001). Characteristics of wet deposition that must be considered in trend analysis include the influence of seasonality on data variability, typically nonnormal data distribution, missing data resulting from data screening steps, and considerable variation in the apparent form of trends exhibited at NADP sites (step-function, linear, or nonlinear). To address these constraints, the trends were analyzed for statistical significance using the Seasonal Mann-Kendall Test (SKT). The SKT is a robust nonparametric test for detection of monotonic trends that implicitly removes the influence of seasonality, while accommodating nonnormal data distributions and missing data. Wet deposition data typically vary strongly with season for many constituents, and the SKT compares only like months in a stepwise, time-ordered fashion to implicitly remove the influence of seasonality.

For ammonium deposition, statistically significant increases were detected at 58 of 149 sites examined, while only 2 sites exhibited declining trends. On a network-wide basis, ammonium deposition increased by

19 percent over the 17-year period of analysis. A number of the sites with increasing trends were located in areas of the country coincident with intensive animal agricultural production—states such as Arkansas, Oklahoma, Kansas, Illinois, and North Carolina. The Northeast region exhibited the fewest positive trends for ammonium concentrations compared to the Southeast and Western United States.

While the majority of sites did not exhibit any trend in nitrate deposition, 23 sites exhibited a significant increasing trend versus 12 sites with a declining trend. Sites with increasing trends in nitrate were predominantly located in the Western and Southeastern United States, while sites with declining trends were located mostly in the Northeast. The median trend of all 149 sites examined was less than +3.0 percent over the 17-year period. Measures to control nitrogen oxide (NO_x) emissions such as those in Title IV of the Clean Air Act Amendments and in mobile source NO_x controls implemented to date have mitigated increases in NO_x, despite substantial increases in power production and vehicle-miles traveled over the past two decades. Hence, the finding here of few observed reductions or increases in NO₃- concentrations in precipitation is consistent with the emission control policy promulgated in the United States over the period examined.

The median concentration of mercury in precipitation at NADP/MDN sites was approximately 10 ng/L in 2001 (NADP, 2002). The highest concentrations of mercury in precipitation occurred in Florida, Minnesota, and Wisconsin. Deposition, which integrates chemical concentration with the amount of precipitation, was highest in the Southeastern United States. Mercury deposition exhibits strong seasonality, with greater concentration and deposition in the warmer months. A preliminary trend analysis of NADP/MDN mercury deposition data at 51 sites for the period 1996–2002 indicated no trend at 42 sites, a downward trend at 8 sites, and an upward trend at 1 site. Irrespective of statistical significance, most of the 51 trend slopes were negative.

The NADP demonstrates the value of a long-term, high-quality national network to gauge the spatial and temporal distribution of wet atmospheric deposition. The network provides an accountability mechanism to gauge the effectiveness of ongoing and future regulations intended to reduce atmospheric chemical emissions and subsequent effects on land and water resources. All NADP data are available at <http://nadp.sws.uiuc.edu/>.

**PATHOGENS IN WATER: ADDRESSING A PUBLIC HEALTH
THREAT VIA THE POTENTIAL SYNERGISM OF THE CLEAN
WATER ACT AND THE SAFE DRINKING WATER ACT**

Joan B. Rose

Waterborne disease statistics and potential risks are divided into recreational outbreaks and drinking water outbreaks. In terms of the current status of waterborne disease in the United States, during the last few years of reporting there has been an increase in disease associated with both drinking water and recreational fresh waters. Enteric bacteria, parasites, and viruses are the key microorganisms associated with these public health risks and are very similar despite the different exposure routes. The largest source of microbial fecal loading and contamination is sewage in the form of untreated and treated wastewaters, combined sewer overflows (CSOs), sanitary sewer overflows (SSOs), and septic tanks and—in the case of bacteria and protozoa—animal excreta. Exposure to untreated sewage has long been known to cause disease. The probability that any waterborne pathogen may cause illness will depend on the type of contact made; exposure; concentration of the organisms in the contaminated water; temperature of the receiving water, which influences survival; transport of the pathogen from source to contact point; and level of individual or population susceptibility to pathogen-borne illnesses. Only a small percentage of outbreaks are documented, as little as 10 percent (Harter et al., 1985). Gastrointestinal illnesses are largely unreported due to the lesser severity of illness in healthy individuals. When etiologic agents have been identified, most often the source of the fecal contamination has not. Thus, the burden of disease is not readily recognized.

While the Clean Water Act (CWA) has focused on protection of recreational waters, the Safe Drinking Water Act has focused on drinking water. In most cases, the different targets, approaches, and regulatory framework have resulted in a disconnection in regard to the protection of public health. Table A.1 shows the comparison in a number of areas.

The CWA has the tools for watershed protection to address sources, survival, transport, and risk, yet none of the rules have addressed pathogens or used a science-based risk assessment approach for examining appropriate public health microbial targets. The SDWA on the other hand has allowed for the use of quantitative microbial risk assessment

TABLE A.1 Comparison of the Clean Water Act and the Safe Drinking Water Act

Area	CWA	SDWA
Goal	Recreational waters, no illnesses while swimming No national standards	Drinking water: health and safety goal, MCLG of zero for pathogen
Focused efforts	On source waters, at the beach area relies on indicators	On treated water, water entering a distribution system, includes pathogen target
Reliance	Minimal monitoring of different targets in different states, in some cases wastewater disinfection and dilution	Daily monitoring, some pathogen monitoring in source waters. Relies on filtration and disinfection
Risk assessment	Used for ecological end points but not for public health	Used for examining pathogen targets, sensitive populations
Pathway forward	Epidemiological studies	Contaminant candidate list
Tools for watershed protection	CAFOs, SSOs, CSOs, NPDES, septic tank permitting, TMDL	Limited under “water quality protection plans”
Pathogen monitoring	No	Yes

NOTE: NPDES=National Pollutant Discharge Elimination System; TMDL=total maximum daily load.

with public health goals but has focused on treatment technology and has little authority for implementing watershed protection approaches except in a few cases. The complementary nature of the two laws is obvious, particularly for freshwater systems; however, changes that focus on pathogen targets in sources would have to be made.

In the future, new challenges will face the water industry and communities struggling with protection of both recreational waters and drinking waters. These may include

- changes in disinfection: ultraviolet disinfection with new microbial targets of resistance such as adenoviruses;
- changes in discharges: blending untreated and treated effluents, greater volumes, animal waste discharges;
- discovery of new microbial contaminants (cancer-causing viruses; zoonotic pathogens); and
- uses and interpretation of molecular data (source tracking, pathogen detection, and virulence factors).

The harmonization of a risk assessment framework to serve the goals of both the Clean Water Act and the Safe Drinking Water Act will ensure that efforts in the future to protect waterways from pathogens will be synergistic.

CHANGE: IMPLICATIONS AT THE WATER–HUMAN HEALTH INTERFACE

Peter H. Gleick

The failure to meet basic human and environmental needs for water is the greatest development failure of the twentieth century—one that carries with it adverse health effects of vast proportions. By the best estimates of the World Health Organization, two million to five million people die annually from preventable water-related diseases that result from lack of safe drinking water and adequate sanitation. In partial recognition of these effects, the United Nations adopted the Millennium Development Goals (MDGs), two of which specifically address water poverty; these call on the world community to work to reduce by half the proportion of people without access to safe drinking water and sanitation services by 2015.

Even if we meet the Millennium Development Goals for water, 34 million to 76 million people will die of preventable water-related diseases by 2020, and we are not going to meet the MDGs given current commitments. Further complications include the broad issue of global change, including geophysical aspects such as global warming and po-

litical and economic aspects associated with rapidly changing population dynamics, political alliances, and economic power. If we are to solve the water problems remaining, new approaches, solutions, and ways of thinking must be applied.

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Appendix A

Workshop Agenda

From Source Water to Drinking Water: Ongoing and Emerging Challenges for Public Health

Sponsored by
The Roundtable on Environmental Health Sciences, Research,
and Medicine

National Academy of Sciences Auditorium
2101 Constitution Avenue, N.W., Washington, D.C.
October 16, 2003

THURSDAY, OCTOBER 16, 2003

- | | |
|-----------|-------------------------------------------------------------------------------------------------------------------------------------|
| 8:30 a.m. | Welcome and Opening Remarks
The Honorable Paul G. Rogers, J.D.
Roundtable Chair
Partner, Hogan and Hartson |
| 8:40 a.m. | Remarks and Charge to Participants
Mike Shapiro, Ph.D.
Deputy Assistant Administrator
U.S. Environmental Protection Agency |
| 9:00 a.m. | Workshop Objectives
Charles Groat, Ph.D.
Roundtable Member
Director, U.S. Geological Survey |

Session I: Status of Science and Policies for Ensuring the Protection of Source Water and Drinking Water

- Moderator: Lynn Goldman, M.D.
Roundtable Vice-Chair
Professor, Johns Hopkins University
- 9:15 a.m. The Interface of Science and Policy: Are the Current Policies Able to Meet Current and Future Challenges
Frederick W. Pontius, P.E.
Pontius Water Consultants, Inc.
- 9:35 a.m. Audience Discussion
- 9:40 a.m. Are Recent Advances in Science and Technology Able to Meet the Health Challenges of Providing Safe Drinking Water?
Jeffrey K. Griffiths, M.P.H., T.M.
Department of Family Medicine and Community Health
Tufts University School of Medicine
- 10:00 a.m. Audience Discussion
- 10:10 a.m. Break

Session II: Assessment and Management Practices—Impact on Health

- Moderator: Christine Moe, Ph.D.
Department of International Health
Emory University
- 10:30 a.m. Source Water Assessment at the State Level
Greg Rogers, M.S.
Texas Commission on Environmental Quality
- 10:50 a.m. Audience Discussion
- 10:55 a.m. Land-Use Planning: A Concern for Source Water Protection?
Douglas L. Hall, M.S.
Manager, Watershed Initiative
Miami Conservancy District
- 11:15 a.m. Audience Discussion

- 11:20 a.m. Impacts of Nonpoint Source Pollution on Drinking Water and Human Health
Tom Christensen, M.S.
Director, National Resource Conservation Service's Animal Husbandry and Clean Water Programs Division
United States Department of Agriculture
- 11:40 a.m. Audience Discussion
- 11:45 a.m. Nutrient Loading: Critical Link in the Chain
Kenneth Reckhow, Ph.D.
Director, Water Resources Research Institute
University of North Carolina
Professor, Nicholas School of the Environment and Earth Sciences
Duke University
- 12:05 p.m. Audience Discussion
- 12:10 p.m. Lunch (provided)

Session III: Emerging Issues in Providing Safe Drinking Water

- Moderator: Yank Coble, M.D.
Immediate Past President, American Medical Association
- 1:00 p.m. Status and Trends in Atmospheric Deposition of Nitrogen and Mercury in the United States
Mark Nilles
Program Manager, U.S. Geological Survey
Office of Water Quality
- 1:20 p.m. Audience Discussion
- 1:25 p.m. Nonregulated Contaminants: Emerging Research. Existing and Future Pollutants in Water Supplies: Old Pollutants, New Concerns—New Pollutants, Unknown Issues
Christian Daughton, Ph.D.
Chief, Environmental Chemistry Branch
National Exposure Research Laboratory, U.S. Environmental Protection Agency
- 1:45 p.m. Audience Discussion

1:50 p.m. Pathogens in Water: Addressing a Public Health Threat via the Potential Synergism of the Clean Water Act and the Safe Drinking Water Act
Joan Rose, Ph.D.
Homer Nowlin Chair for Water Research
Department of Fisheries and Wildlife, Michigan State University

2:10 p.m. Audience Discussion

Special Address

2:15 p.m. Change: Implications at the Water–Human Health Interface
Peter Gleick, Ph.D.
President, Pacific Institute for Studies in Development, Environment and Security

2:45 p.m. Audience Discussion

3:00 p.m. Break

Session IV: Charting a Course for the Future

3:15 p.m. Panel Discussion. Panelists were asked to react to the earlier discussions and answer questions that lay out the challenges to health:

- Have we missed any of the new stressors at the interface of source water and drinking water?
- How important are these stressors to human health?
- If these stressors are important, where do we go from here?
- Where are we in the process of meeting these challenges?
- Is there a disconnection between the Clean Water Act and the Safe Drinking Water Act? If so, how will we balance recreation, ecological protection, and drinking water sources?

Moderators: Richard Harris, National Public Radio
James Crook, Ph.D., P.E., Principal Water Reuse Consultant
Cynthia Dougherty, Director, Office of Ground Water and Drinking Water, U.S. Environmental Protection Agency
Barker Hamill, P.E., Chief of the New Jersey Department of Environmental Protection Bureau of Safe Drinking Water

Brian Ramaley, P.E., Director, Public Utilities, City of Newport News, Virginia
Kenneth Reckhow, Ph.D., Director, Water Resources Research Institute, University of North Carolina
Paul Schwartz, National Policy Coordinator, Clean Water Action
Susan Seacrest, M.S., President, Groundwater Foundation

3:45 p.m. General Discussion

4:45 p.m. Final Summation
Henry Falk, M.D., M.P.H.
Assistant Administrator, Agency for Toxic Substances and Disease Registry
Director, National Center for Environmental Health Centers for Disease Control and Prevention

5:00 p.m. Adjourn

Appendix B

Speakers and Panelists

Tom Christensen, M.S.
Director
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Yank D. Coble, M.D.
Immediate Past President
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Appendix C

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