United States General Accounting Office

GAO

Report to Congressional Requesters

June 2001

ENVIRONMENTAL PROTECTION

Wider Use of Advanced Technologies Can Improve Emissions Monitoring

GAO

Accountability * Integrity * Reliability

GAO-01-313

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Abbreviations

CEMS	Continuous Emissions Monitoring Systems
EPA	Environmental Protection Agency
ETV	Environmental Technology Verification
GAO	General Accounting Office
GIS	Geographic Information Systems
ICP/MS	Inductively Coupled Plasma/Mass Spectrometer
OMB	Office of Management and Budget
PEMS	Predictive Emissions Monitoring Systems
TMDL	Total Maximum Daily Loads
USGS	U.S. Geological Survey

United States General Accounting Office
Washington, DC 20548

June 22, 2001

The Honorable Sherwood L. Boehlert
The Honorable Cal Dooley
The Honorable James Greenwood
House of Representatives

As requested, we are reporting on the use and development of monitoring technologies for measuring emissions from stationary air, point water, and nonpoint water sources of pollution.

As arranged with your offices, unless you publicly announce its contents earlier, we plan no further distribution of this report until 30 days from the date of this letter. At that time, we will send copies to the appropriate congressional committees; the Honorable Christine Todd Whitman, Administrator, EPA; the Honorable Gale Norton, Secretary of the Interior; and the Honorable Mitchell Daniels, Director, Office of Management and Budget. We will also post this report on the Internet at www.gao.gov and make copies available to others upon request.

Please call me at (202) 512-3841 if you or your staff have any questions. Major contributors to this report are listed in appendix II.

John B. Stephenson
Director, Natural Resources
and Environment

Executive Summary

Purpose

The U.S. Environmental Protection Agency (EPA) was established in 1970 to consolidate in one agency a variety of federal research, monitoring, standard setting, and enforcement activities to ensure environmental protection. EPA's mission is to protect human health and to safeguard the natural environment. This includes regulating pollution generated by facilities such as sewage treatment plants, power generation plants, chemical manufacturers, and pulp and paper mills. Pollution can pose serious threats to human health, wildlife, and other natural resources, and degrade overall environmental conditions. Monitoring is a key component of the efforts by both the government and private parties to address these threats. Effective monitoring is critical to ascertain where the key pollution problems exist, what their consequences may be, and how they can be most effectively remedied. It is also an essential element of the government's efforts to determine compliance with existing laws and regulations. In addition, monitoring has served in recent years as an essential ingredient in regulatory flexibility efforts. Such efforts are intended to provide regulated entities the flexibility to determine how they meet limits on the pollutants they discharge, while ensuring through effective monitoring that environmental standards are still met.

Many of the technologies that are currently used to monitor environmental conditions have been in use for several decades. In recent years, however, a number of technologies have been identified that may offer improved measurement and performance capabilities. Concerned that many of these improved technologies are not being used to their full potential, GAO was asked to (1) identify technologies whose wider use can improve the monitoring of pollutants entering the nation's air and water; (2) determine the extent to which these improved technologies are being used and steps that EPA can take to encourage their wider use; and (3) identify the factors that influence the development of new technologies and steps that EPA can take to encourage greater development of new technologies. As agreed with the Offices that requested this report, GAO focused its review on monitoring technologies associated with air emissions from stationary sources, wastewater discharges from "point" water sources, and pollution from diffused "nonpoint" water sources.

Background

While the Clean Air Act and the Clean Water Act each require facilities to limit their pollutant discharges, the two federal environmental laws address pollutant monitoring very differently. Under the Clean Air Act, EPA requires about 20,000 of the largest pollution sources to obtain permits that consolidate all applicable air pollution control requirements. Each permit contains all required monitoring and analysis procedures. A limited number of facilities in certain industries must continuously measure their emissions of some pollutants. Most other facilities, however, do not and rely instead on short-term tests and other indicators of compliance. As a result, regulators and regulated entities sometimes lack certainty about whether these facilities maintain continuous compliance with clean air regulations.

Facilities that discharge pollutants, or wastewater, into waters of the United States from a discrete point, such as a pipe, are regulated by a Clean Water Act program that requires facilities to monitor their discharges in order to ensure compliance with pollutant discharge limits. Regulated entities must use only EPA-approved test methods. The degree of monitoring required depends on the type and amount of pollution that a facility emits. However, there is a much greater degree of monitoring of pollutant discharges from wastewater sources than from stationary air sources, mainly because all wastewater sources that discharge into a body of water, regardless of size, are required to have a pollutant discharge permit. There are about 96,000 facilities that have a pollutant discharge permit under this program.

Water pollution that cannot be traced to a pipe or other discrete conveyance is known as “nonpoint source” pollution. Nonpoint source pollution is caused by such activities as agriculture, forestry, and urban development. The diffuse nature of nonpoint sources makes their direct measurement exceedingly difficult. Therefore, measuring nonpoint source pollution entails analyses of multiple types of data, including water quality conditions, land use, climate, and soil type. Mathematical models are often used to translate these data into probable pollutant contributions from individual sources or groups of similar types of sources. While nonpoint sources, in general, are identified as contributors to most of the nearly 300,000 miles of rivers and streams and about 8 million acres of lakes that do not meet water quality standards, there is no estimate for how many sources actually contribute pollutants.

Efforts have long been underway to develop improved technologies to enhance the monitoring of air and water quality. These efforts have generally sought to (1) better enable regulators and regulated parties to detect pollution problems and ascertain whether pollutant levels exceed regulatory standards, (2) ascertain whether emitters are complying with specific limitations listed in their permits, and/or (3) reduce monitoring costs. Recent proposals to allow regulated parties greater flexibility in achieving emissions or discharge limitations have given the search for improved monitoring technologies added impetus. One such proposal introduced in the 106th Congress was entitled, “The Second Generation of Environmental Improvement Act” (H.R. 3448). Among other things, the bill would allow EPA to enter into “innovative strategy agreements” with states, companies, or other interested parties in order to achieve environmental standards more efficiently and effectively. Such agreements could involve the modification or waiver of agency regulations. Noting that such regulatory flexibility should be accompanied by “greater accountability through enhanced monitoring and data reporting,” the bill contained a number of provisions intended to improve monitoring and other measurement methods.

Results in Brief

A number of monitoring technologies exist that can improve the capability to measure the emission or discharge of pollutants from stationary air sources, wastewater sources, and nonpoint water sources. These technologies offer improvements over older, more commonly used methods by detecting pollutants at lower levels, reducing monitoring costs, and/or increasing the reliability of monitoring results. For example, Continuous Emissions Monitoring Systems (CEMS) continuously measure pollutants released by stationary air sources. EPA officials consider CEMS to be the most reliable method for determining emissions. Promising wastewater monitoring technologies include inductively coupled plasma/mass spectrometry (ICP/MS) and ion chromatography, both of which can (1) detect pollutants at significantly lower levels than commonly used monitoring technologies and (2) reduce costs for users by rapidly analyzing multiple pollutants in a single sample rather than analyzing them one at a time.

Most improved monitoring technologies have existed for years but are not widely used. The primary barriers preventing wider use of these technologies differ considerably across stationary air, wastewater, and nonpoint water sources. Regarding emissions from stationary air sources, a major disincentive to wider use of advanced technologies by regulated entities is their potential to identify instances of noncompliance and violations. To date, EPA requires only a limited number of industries (primarily electric utilities) to use continuous emissions monitors. Regarding monitoring of wastewater discharges, GAO found that the majority of dischargers are unable to use advanced technologies, such as ICP/MS, because EPA has yet to specifically approve the technologies for Clean Water Act compliance monitoring. Users cited a lengthy and cumbersome EPA approval process and EPA’s funding constraints as the principal reasons why they do not more widely use technologies such as the ICP/MS and the ion chromatograph. Regarding monitoring technologies for nonpoint water sources, while federal approval is not needed, wider use of these technologies has been discouraged by concerns over the cost of purchasing some of the technologies and the expertise required to use them.

Equipment manufacturers develop new technologies only when strong prospects exist for a return on their investments. Accordingly, many of the constraints that impede the use of existing advanced monitoring technologies have limited such investments. In the case of air monitoring technologies, equipment manufacturers and regulators said that, without regulatory requirements, manufacturers have little incentive to bring new technologies to market. In the absence of private investment, government agencies, including EPA, the Department of Defense, and the Department of Energy, have sponsored some research in this area, but EPA has limited resources and research conducted by other agencies does not always provide results that are acceptable for regulatory purposes. Developers of wastewater monitoring technologies have had some success in obtaining approval for minor modifications to existing EPA methods as well as proposed methods to be used by individual facilities. However, the approval process for major advances with nationwide application has deterred investment in these more far-reaching technologies.

Principal Findings

Available Technologies Can Often Improve Monitoring and Reduce Costs

Stationary sources of air pollution vary in the extent to which they monitor their compliance with clean air regulations. Some of the largest emitters, such as many electric utilities, must continuously monitor their emissions of certain pollutants. Many sources, however, rely on other indicators of compliance, such as short-term tests or periodic monitoring. As a result, regulators and regulated entities sometimes lack certainty about whether these facilities continuously comply with clean air regulations. Continuous Emissions Monitoring Systems (CEMS) are capable of continuously measuring and recording emissions of certain air pollutants using a variety of sampling and analytical methods. EPA officials consider CEMS to be the most reliable method for determining emissions. In addition to providing a continuous indication of a facility's compliance status, these devices can provide facilities with information that enables them to identify process improvements that could save them money and reduce emissions.

In the case of wastewater discharges, ICP/MS has long been recognized for its potential to provide greater accuracy and, in some cases, to dramatically lower costs. In fact, a 1988 EPA report predicted that during the 1990s, "the application of inductively coupled plasma/mass spectrometry to environmental analyses could result in the single greatest impact on the analysis of metals." Ion chromatography provides similar benefits when measuring inorganic substances, such as nitrates and phosphates. Like ICP/MS, it can rapidly analyze multiple pollutants in a single sample, as opposed to methods currently used for wastewater monitoring that can analyze only one pollutant at a time. As a result, ion chromatography can reduce costs at commercial laboratories or large regulated facilities that test numerous samples. In addition, ion chromatography has detection levels in the parts-per-billion range, which is considerably lower than methods currently in use.

The importance of identifying and measuring nonpoint sources of pollution stems from intense pressure on the states and EPA to address the thousands of waters that do not meet water quality standards as a result of these sources. However, traditional water quality monitoring techniques, such as in-person sampling, are too costly and labor-intensive to monitor a sufficient number of waters. Technologies are available, however, that can increase the amount of sampling that can be done and provide water quality measurements more quickly. For example, some "field-based" tools can take measurements of various water quality parameters on-site, which eliminates certain laboratory analyses and provides more immediate information. In addition, computerized models, which automate the analysis of the complex relationships that define how water pollutants move through the environment (an extremely difficult and time-consuming analysis if conducted manually), have been made easier to use so that more entities conducting nonpoint assessments can utilize these tools.

Improved Monitoring Technologies Used to a Limited Extent

Many improved technologies have been used to only a limited extent despite their proven track record. The reasons for this, however, vary among air, wastewater, and nonpoint water monitoring technologies. A major barrier to voluntary use of air emissions monitoring technologies by regulated entities is the concern that improved monitoring will reveal violations of clean air regulations that will result in punitive action. As a result, regulated entities perform monitoring only when required to do so. EPA, however, typically does not require emitters to use these technologies, due primarily to time and resource constraints in issuing new regulations, as well as the perception that they are too expensive.

The direct measurement of pollutant discharges from wastewater sources is significantly greater than from stationary air sources, stemming largely from a Clean Water Act program's requirement that virtually all wastewater sources that discharge pollutants into U.S. waters monitor their compliance with a discharge permit. Yet, while this more comprehensive monitoring framework would appear to encourage use of improved technologies for monitoring Clean Water Act compliance, GAO found that few regulated dischargers use ICP/MS or the ion chromatograph for this purpose, despite the fact that these technologies are routinely used to monitor compliance with the Safe Drinking Water Act. The main reason that many dischargers do not use these technologies is because the monitoring methods are not yet approved for use by EPA, meaning that a facility could be found in noncompliance for using an unapproved method. And while EPA had proposed approving the use of ICP/MS and the ion chromatograph for wastewater compliance monitoring in the mid-1990s, agency officials said that funding constraints prevented the agency from doing the additional validation studies needed to support an approval decision. In particular, they pointed out that the amount of funding devoted to developing and validating methods for use in compliance monitoring has declined by over 50 percent since fiscal year 1997.

It is difficult to determine the extent of a particular nonpoint source water monitoring technology's use because (1) the different entities doing nonpoint assessments are free to use any technology they choose and (2) there is a multitude of ongoing nonpoint source pollution assessments across the country. However, based on discussions with a diverse group of participants in this type of monitoring and assessment, it appears that cost and simplicity are major factors that influence their use. Hence, most states are using automatic samplers and field-based analytical devices to meet at least some of their monitoring and assessment requirements because the technologies are relatively affordable and easy to use. Similarly, states doing nonpoint source water assessments use simplified models that have been enhanced in recent years with improved interfaces and graphical output.

On the other hand, Geographic Information Systems (GIS), remote sensing, and highly complex models, are used to a much lesser extent. Many officials that GAO contacted cited the cost of purchasing such technologies and the skills needed to operate and maintain them as major barriers. Some officials added that states may be unwilling to experiment with less-proven technologies because of their programmatic demands to conduct a large number of assessments within fairly tight timeframes.

Thus, the most advanced nonpoint source monitoring technologies are used more frequently by research organizations or in special projects conducted by states or interagency programs. Many officials noted the benefits of using any of these advanced technologies include collecting more reliable information or conducting more complex analyses, which will ultimately help them make more informed decisions regarding needed pollution controls.

Factors Influencing the Development of New Technologies

According to air monitoring equipment manufacturers and regulators, manufacturers have little incentive to bring new monitoring technologies to market in the absence of an identified need to satisfy a regulatory requirement. As a result, most improvements focus on making existing monitoring methods more reliable and less expensive. Given the limited private investment in this area, EPA's Science Advisory Board recommended in 1995 that the agency support the development and commercialization of more innovative CEMS and other technologies. According to agency officials, EPA devotes a limited amount of funding to the development of advanced technologies, but this focuses on agency research objectives rather than bringing promising technologies to market. Other federal agencies also perform research and development, but these efforts do not always provide results that are acceptable for regulatory purposes.

Manufacturers and vendors of wastewater monitoring technologies cited as their primary deterrent the time required to navigate their most significant technological proposals—those involving major modifications or new monitoring methods with nationwide application—through a complicated EPA technical and administrative rulemaking process. Between fiscal years 1993 and 2000, EPA approved two such "nationwide use" methods, taking about 3 years for one and about 3-½ years for the other. The sponsor of a third case, currently in the rule making process, projects that the total period of review will be about 5 years before the proposed method is published as a final rule. A wide variety of organizations GAO contacted, including state regulatory authorities, regulated entities, and equipment manufacturers, voiced concern over the length of this process. Equipment manufacturers told GAO that the EPA review process had at least partly influenced their decision to apply their water monitoring technologies to other markets, such as the pharmaceutical and biotechnology industries. Others told GAO that they are focusing more of their attention on overseas markets.

Several factors limit the market for advanced technologies for use in nonpoint source assessments. In particular, manufacturers told GAO that since there are no specific requirements regarding how states must monitor their waters, there is no clearly defined market for their products. Compounding this risk is the relative scarcity of shared information between the users and the developers of these technologies. Several officials that GAO interviewed consistently stated that information sharing about past successes and failures using certain technologies and techniques needs to be improved. Without such information, it is difficult to know where additional technologies are needed. Finally, investment in nonpoint source pollution monitoring by the largest group of users—the states—has historically been light, given their water programs' historic focus on wastewater sources. Consequently, instrument manufacturers told GAO that they believe the market for new products in this area is relatively limited.

Recommendations

Because monitoring requirements vary considerably for air, wastewater, and nonpoint source water pollution, GAO makes separate recommendations to the Administrator, EPA, at the end of chapters 2, 3, and 4, respectively. The recommendations in chapter 2 identify steps that EPA should take to encourage wider use of advanced air monitoring technologies. Recommendations in chapter 3 focus on improving and maintaining EPA's process for approving new monitoring methods or modifications to existing ones for use in wastewater compliance monitoring. The recommendation in chapter 4 addresses the need for improved information sharing regarding successes and failures of new monitoring technologies and assessment techniques given the decentralized nature of nonpoint source pollution management.

Agency Comments

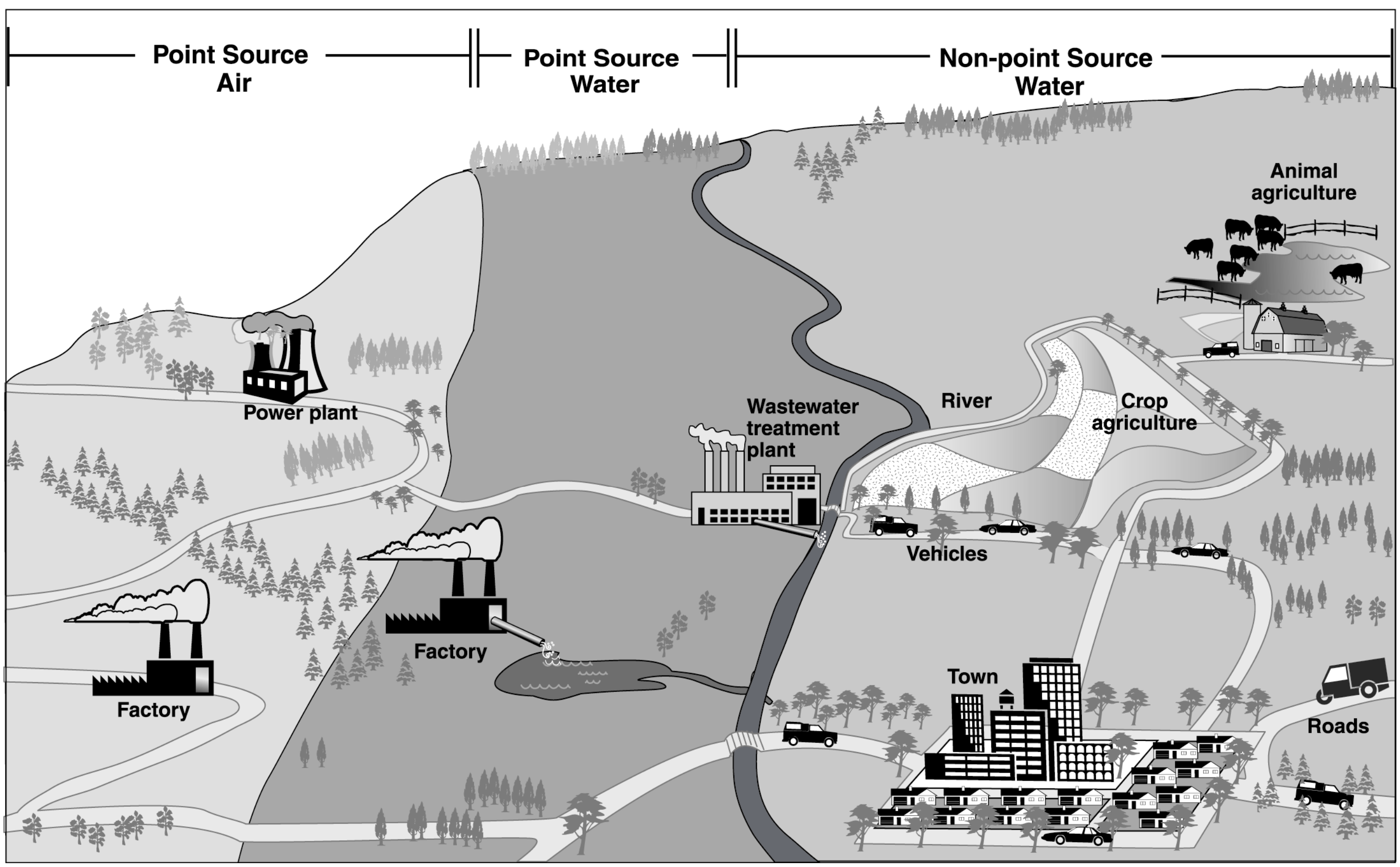
GAO provided EPA and the Department of the Interior with a draft of this report for review and comment. In its letter dated June 12, 2001, Interior said that it agreed with the recommendation in chapter 4 that EPA develop a clearinghouse and/or locator for monitoring technologies and assessment techniques that are used for assessing pollutant contributions from nonpoint water pollution sources and developing Total Maximum Daily Loads. It suggested, however, that the report note that to some extent, several agencies have already moved in this direction through the establishment of a National Environmental Monitoring Index, which falls under the auspices of the interagency National Water Quality Monitoring Council. GAO added language to this effect in chapter 4 and incorporated several other technical comments and clarifications suggested by the Department.

EPA did not submit a formal letter but supplied GAO with individual comments from several of the offices with jurisdiction over the issues discussed in the report. Commenting on the report's discussion of air monitoring technologies, the Office of Air and Radiation said it believed that "the subject is covered accurately and the conclusions are fair." The Office provided a number of editorial comments, which were incorporated as appropriate. The Office of Research and Development provided input from several individuals within the office. Among the key themes from these comments were that the report should provide more detailed information on the range of available monitoring technologies, the type of improvements that are necessary, and the benefits of improved monitoring. GAO believes that it was limited in the level of detail the report should devote to these matters by (1) the enormous range of technologies that address air, wastewater, and nonpoint source water monitoring and (2) the need to devote sufficient attention in the report to the legal and regulatory barriers inhibiting wider use and development of such technologies, which was the primary focus of the report. Other comments by reviewers from the Office of Research and Development are discussed at the end of chapter 2. The EPA Offices of Water and of Enforcement and Compliance Assurance also reviewed the draft report but did not provide comments.

Chapter 1: Introduction

Sewage treatment plants, power generation plants, chemical manufacturers, and pulp and paper mills are among the facilities that emit or discharge various pollutants into the air and water. Urban development and agriculture also contribute pollutants to our environment, although often in a much more "diffused" manner (see fig. 1.) Pollutants from all of these facilities and activities can pose serious threats to human health—sometimes immediately upon contact when encountered in sufficient quantities; other times through long-term exposure to smaller quantities. Many pollutants also damage wildlife and other natural resources, and degrade overall environmental conditions. The primary purpose of the Clean Air Act and the Clean Water Act is to regulate emissions of these pollutants.

Figure 1: Sources of Pollution



The systematic monitoring of pollutants is an essential function under both statutes. It is particularly critical in determining where the key pollution problems lie, what their consequences may be, and how they can be most effectively remedied through pollution control strategies. It is also an essential element of the government's efforts to determine compliance with existing laws and regulations. In addition, monitoring has served in recent years as an essential ingredient in innovative environmental protection programs, such as emissions trading. Such efforts are intended to provide regulated entities with flexibility in how they meet limits on the pollutants they discharge, while ensuring through effective monitoring that environmental standards are still met. While the monitoring requirements of the Clean Air Act and the Clean Water Act share some similarities, there are also important differences.

Monitoring Facility Emissions Under the Clean Air Act

Facilities that emit pollutants into the air—generally referred to as "stationary air sources"—must comply with the emissions limitations and other provisions of the Clean Air Act. Under the act, EPA requires some facilities to limit or control their emissions of certain pollutants and monitor their compliance with applicable clean air regulations.

Compliance monitoring requirements for individual facilities depend on factors such as the type of facility and the amount of pollution it emits. Some sources, such as many electric utilities, must continuously monitor their emissions of certain pollutants. Most sources, however, instead perform temporary emissions tests when they first install pollution control equipment. Some of these facilities may, but do not necessarily, undergo additional temporary monitoring (or "periodic monitoring") at the discretion of their state air pollution control agency. As a result, regulators and regulated entities sometimes lack the certainty that these facilities maintain continuous compliance with clean air regulations. An EPA enforcement official said that, in general, regulated entities must maintain continuous compliance with applicable requirements adopted and approved under the Clean Air Act.

Monitoring Discharges Under the Clean Water Act

Facilities that discharge pollutants into waters of the United States from a discrete point, such as a pipe, are referred to as "wastewater dischargers." Facilities include industrial operations, such as coal mining or iron manufacturers, or other operations, such as sewage treatment facilities. These three categories of dischargers account for 95 percent of all discharges. Under a Clean Water Act program, all wastewater dischargers must obtain a permit that generally includes effluent limitations and monitoring requirements. Regulated entities must use approved EPA methods for monitoring that describe procedures for measuring pollutants. The degree to which monitoring is required depends on the type and amount of pollution a facility emits. Overall, wastewater dischargers are more likely to regularly measure their emissions than are regulated air pollution sources. This more comprehensive monitoring framework stems largely from the Clean Water Act program's requirement that virtually all wastewater sources discharging pollutants into U.S. waters have a pollutant discharge permit, regardless of size.

In addition to facilities that discharge pollutants directly to waters, pollutants may also be discharged into waters by a wide variety of "nonpoint sources" of pollution. Nonpoint sources are diffused sources associated with land-based activities such as agriculture, timber harvesting, and urban development. While these activities generate and eventually discharge pollutants to waters, unlike wastewater sources, their discharges do not go through a pipe or other discrete conveyance. The Clean Water Act directs states to develop programs that address nonpoint source pollution but provides no direction for the establishment of minimum national controls and/or monitoring that must be implemented, such as it does for the control of wastewater. As a result, state laws and programs bearing on nonpoint source water pollution vary widely.

Without a clearly identified source of discharge, the direct measurement of pollutant contributions from nonpoint sources remains exceedingly difficult. Assessing nonpoint source pollution entails synthesizing and analyzing multiple types of data, including water quality conditions, land use, climate, and soil type. Mathematical models are often used to translate these data into probable pollutant contributions from individual sources or groups of similar types of sources.

State agencies that regulate water quality typically take the lead in monitoring for nonpoint source pollution. Because no specific program requirements exist regarding monitoring, assessing, or controlling nonpoint sources, the use of particular monitoring technologies or assessment techniques is not strictly controlled—a major difference between this and the monitoring of stationary air emissions and wastewater discharges. In addition, numerous federal, state, local, and other organizations often monitor water quality conditions and generate other types of data used in nonpoint source analyses.

The Search for Improved Monitoring Technologies

Efforts have long been underway to improve the ability of regulators and regulated parties to detect pollution problems, ascertain whether pollutant levels exceed regulatory standards, and reduce monitoring costs. Research and development of advanced monitoring technologies is conducted by many different organizations such as federal agencies, universities and other research-oriented institutions, and private vendors of such technologies.

According to a 1998 Department of Commerce report, the business sectors most related to environmental monitoring—analytical services, instruments, and information systems—accounted for about 2 percent of the U.S. environmental industry's revenues ($4.3 billion out of $181 billion) in 1996. In that year, these sectors included 2,100 companies and over 42,000 employees. Air and water monitoring revenues accounted for a little more than one-half of overall revenues for these sectors, about $0.9 billion and $1.4 billion, respectively in 1996. The report noted that investment in the environmental industry posed significant risks, stating that "most investors perceive the risks of environmental investment as especially difficult to overcome, and believe that the environmental market is riskier than others."[1]

Recognizing the need to accelerate the development and commercialization of improved environmental technologies, EPA established the Environmental Technology Verification program in 1995. This program verifies the performance of commercially ready technologies and, according to EPA, provides independent and credible assessments to potential buyers. EPA relies on various stakeholder groups to prioritize the technologies to be analyzed. As of September 2000, the program had verified 111 technologies.

Recent proposals to allow regulated parties greater flexibility in achieving emissions or discharge limitations have given added impetus to the search for improved monitoring technologies. One such proposal, "The Second Generation of Environmental Improvement Act" (H.R. 3448), was introduced in the 106th Congress. H.R. 3448 noted that "Numerous studies have recommended experimenting with performance-based regulatory approaches that provide regulated entities with greater flexibility in

[1] See *Meeting the Challenge: U.S. Industry Faces the 21st Century; The U.S. Environmental Industry*, Office of Technology Policy, U.S. Department of Commerce (Sept. 1998).

determining how to meet environmental standards." The bill stated, however, that such flexibility should be accompanied by "greater accountability through enhanced monitoring and data reporting." Toward this end, the bill contained a number of provisions intended to improve monitoring and other measurement methods.[2]

Objectives, Scope, and Methodology

Members of Congress Boehlert, Dooley, and Greenwood asked us to (1) identify technologies whose wider use can improve the monitoring of pollutants entering the nation's air and water; (2) determine the extent to which these improved technologies are being used and steps that can be taken to encourage their wider use; and (3) identify the factors that influence the development of new technologies and steps that can be taken to encourage greater development of new technologies. As agreed, our review focused on monitoring technologies associated with stationary air emissions and both wastewater and nonpoint source water discharges.

To address the first two objectives, we interviewed numerous representatives of relevant government agencies and private organizations, reviewed existing literature, and analyzed available EPA data. Of particular note, we interviewed officials from EPA's Offices of Water, Air and Radiation, and Research and Development who are responsible for conducting research in monitoring technologies, evaluating technologies developed by private organizations, and implementing clean air and clean water programs. We also obtained and analyzed available EPA data on the timeframes for making decisions on proposals for using alternative technologies for compliance monitoring. We also spoke with officials from EPA's Office of Enforcement and Compliance Assurance to better understand the effect of the agency's enforcement regulations and policies on the use of improved monitoring technologies. In addition, we contacted officials from the U.S. Geological Survey and the Department of Energy who are involved in conducting environmental monitoring and sponsoring research in environmental monitoring technologies.

[2] Among other things, the bill's section 106 provided that the EPA Administrator establish a program to publicly recognize efforts to develop and make more effective use of improved monitoring technologies and to develop technologies and other methods that reduce the costs of collecting or disseminating monitoring data. The bill also contained other requirements intended to encourage EPA to reduce the time required to approve new monitoring technologies and to expedite their deployment.

We also contacted many public and private organizations that have either developed improved monitoring technologies or have participated in decisions affecting their use by regulated emitters of air and water pollutants. These organizations include state environmental regulatory agencies, academic and research institutions, standards boards, such as the American Society of Testing and Materials, industry associations, and technology manufacturers or vendors.

To obtain further insights into the extent to which these technologies are being used, we obtained data from relevant agency databases that contain information on regulated entities and, in some cases, monitoring requirements and the technologies being used to meet them. We also interviewed state and federal regulatory agencies and regulated entities to gain their perspective on this issue.

We also interviewed representatives of regulated entities to better understand the incentives and disincentives surrounding the use of improved air and water monitoring technologies. In selecting these organizations, we sought diversity in the size and type of facility and the nature of the emissions discharged. To obtain more detailed insights and "hands-on" information, we visited the Hampton Roads Sanitation District in Hampton, Virginia, and Dominion Power's Possum Point Power Plant in Dumfries, Virginia. At each location, we examined the monitoring instruments currently in use, and discussed with company officials the factors that affected their decisions and their ability to use more advanced monitoring methods.

To address the factors that affect the development of new monitoring technologies, we concentrated mainly on the views of the instrument manufacturers, public and private research organizations, and other organizations whose decisions most directly influence the nature and extent of investment in developing new monitoring technologies. We identified the factors affecting their investment decisions, as well as the implications these decisions would likely have on the future availability of improved monitoring technologies. We also attended EPA's annual conference on monitoring technologies for various media, EPA's national conference on nonpoint source monitoring, and a conference on air monitoring technologies.

We conducted our work from September 2000 through May 2001 in accordance with generally accepted government auditing standards.

Organization of This Report

Most GAO reports are organized in a manner that addresses each evaluation question sequentially (as is done in the executive summary of this report). However, the detailed information in the chapters of this report has been structured somewhat differently because of the complexity of the technologies discussed and the relatively unique issues concerning the monitoring technologies associated with air, wastewater, and nonpoint source water pollution. Accordingly, chapter 2 addresses the three evaluation questions as they relate to stationary air pollution sources; chapter 3 addresses the three questions as they relate to wastewater pollution sources; and chapter 4 addresses the questions as they relate to nonpoint water pollution sources.

Chapter 2: Technologies for Measuring Emissions From Stationary Air Sources

Regulated stationary sources of air pollution vary in the extent to which they must monitor their emissions. Some sources, such as many electric utilities, must continuously monitor their emissions of certain pollutants. Most other facilities, however, do not and rely instead on short-term tests and other indicators of compliance. As a result, regulators and regulated entities sometimes lack certainty about whether these facilities maintain continuous compliance with clean air regulations. Technologies are available that could improve these facilities' capacity to monitor their air emissions and their compliance with clean air regulations. Accordingly, our discussion of advanced air monitoring technologies focuses on commercially available technologies that can assist regulated entities in monitoring compliance. These technologies can also help facilities better understand their processes and identify opportunities to improve productivity and reduce waste.

Despite these incentives, we found that regulated facilities generally utilize advanced technologies only when required for regulatory purposes. However, EPA rarely requires continuous compliance monitoring because of time and resource constraints in issuing new rules, as well as the perception that advanced monitoring technologies are too expensive. Voluntary use of advanced technologies by regulated entities is also rare because of the concern that improved monitoring will reveal violations of clean air regulations. These factors limit not only the use of advanced technologies, but also corporate investments in research and development of new technologies.

Compliance Monitoring Under the Clean Air Act

The Clean Air Act is a comprehensive environmental law that regulates air emissions from stationary and mobile sources. Under the act, EPA regulates six "criteria" pollutants to protect public health: carbon monoxide, lead, nitrogen dioxide, particulate matter, sulfur dioxide, and ground-level ozone. (The latter is not directly emitted by stationary sources, but forms through the airborne reaction of heat and sunlight with nitrogen oxides and volatile organic compounds.) In addition to the six criteria pollutants, EPA regulates 188 hazardous air pollutants known as air toxics. People exposed to toxic air pollution—which can be highly localized near industrial sources—have an increased chance of getting cancer and other serious health effects.

For the purposes of the Clean Air Act, stationary air pollution sources fall into two categories: major sources and minor sources. Generally, major sources are facilities that annually emit or have the potential to emit annually (1) 10 or more tons of any one toxic air pollutant; (2) 25 tons of any combination of toxic air pollutants, or (3) 100 or more tons of any of the six criteria pollutants.[1] An EPA official said that, as of January 2001, there were approximately 20,000 major sources; EPA data show that there were about 53,000 facilities classified as point sources in 1996.[2]

Each year, industrial operations in the United States emit nearly 100 million tons of pollutants into the air. Table 1 shows the five largest industrial sources of criteria pollutants (excluding lead) and volatile organic compounds in 1998 (the most recent data available). Large stationary sources accounted for 19 percent of total criteria pollutant emissions (excluding lead) in 1998. Small stationary sources and mobile sources such as cars, trucks, and buses accounted for the remaining 81 percent.

Table 1: Largest Stationary Sources of Criteria Pollutants (excluding lead) and Volatile Organic Compounds, 1998

Source	Level of emissions (tons)	Proportion of total from large stationary sources (percentage)
Coal-powered electric utilities	18,377,073	52
Industrial fuel combustion (coal, gas, and other)	5,333,899	15
Chemical manufacturing	1,961,876	6
Ferrous metal processing	1,756,146	5
Mineral products	1,004,962	3
Other sources	6,739,181	19
Total	**35,173,137**	**100**

Source: EPA

Table 2 identifies the five largest major source emitters of toxic air emissions in 1996 (the most recent data available). Major sources accounted for about 24 percent of the emissions of toxic air pollutants in 1996.

[1]The definition of a major source also depends on the air quality in its geographic area. For example, sources that emit as little as 10 tons a year of volatile organic compounds may be classified as major sources in areas with poor air quality.

[2]EPA officials said that the agency does not maintain complete information on the total number of minor sources.

Table 2: Five Largest Major Stationary Source Emitters of Toxic Air Emissions, 1996

Source	Level of emissions (tons)	Proportion of total from major sources (percentage)
Utility boilers	408,747	36
Petroleum refineries	80,369	7
Pulp and paper production	59,810	5
Metal parts coating	50,921	5
Polymer and resin manufacturing	35,546	3
Other major sources	492,407	44
Total	**1,127,800**	**100**

Source: EPA

Some sources, such as many electric utilities, must measure their emissions of certain pollutants continuously. Most sources, however, instead perform temporary emissions tests to verify performance when they first install pollution control equipment. Some of these facilities may, but do not necessarily, undergo additional ongoing monitoring (or "periodic monitoring") of the pollution control measures at the discretion of their state air pollution control agency. As a result, regulators and regulated entities sometimes lack certainty about whether these facilities maintain continuous compliance with clean air regulations. According to EPA's Office of Enforcement and Compliance Assurance, in general, regulated entities must maintain continuous compliance with applicable requirements adopted and approved under the Clean Air Act.

According to EPA officials, when facilities are required to measure emissions for regulatory compliance, they must use EPA developed and approved test methods (for periodic or continuous monitoring) or performance specifications (for continuous monitoring). As of August 2000, EPA had developed and approved 11 performance specifications covering a variety of pollutants and continuous monitoring technologies. In addition, EPA has developed and made available over 100 approved test methods that address the criteria air pollutants and certain air toxics, such as mercury.[3] An EPA official said that the agency also allows the submittal

[3] According to EPA's Office of Air and Radiation, methods for certain pollutants do not apply to all sources. EPA said that, for example, the agency has an approved method for monitoring mercury emitted by waste combustors, but not from electric utilities.

of alternative test procedures and will approve these alternatives if the agency determines that they provide an adequate level of certainty.

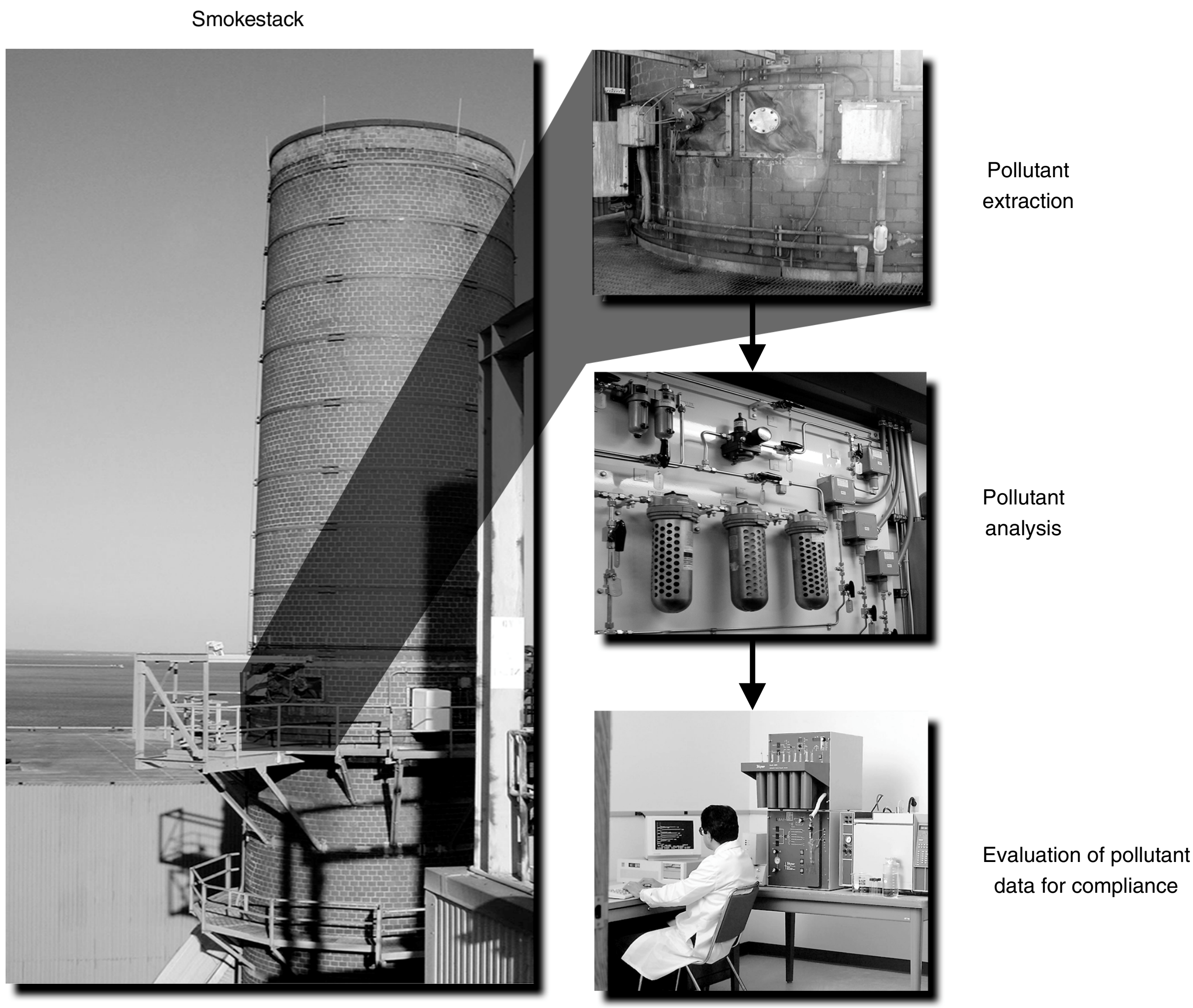
Available Technologies That Can Improve Monitoring of Air Emissions

Overall, we found that commercially available technologies could assist in monitoring compliance with clean air regulations and in identifying process and efficiency improvements that could lead to decreased use of raw materials and reduced emissions. Many of these technologies, including those that monitor criteria and toxic air pollutants, provide continuous measurement of emissions or operating parameters that correlate to emissions.

Continuous Emissions Monitoring Systems

EPA officials consider Continuous Emissions Monitoring Systems (CEMS) to be the most reliable method for determining emissions. In contrast to periodic monitoring, these devices continuously measure pollutants released by a source. Some CEMS extract a gas sample from a facility's exhaust and transport it to a separate analyzer while others allow effluent gas to enter a measurement cell inserted into a stack or duct (see fig. 2).

Figure 2: Example of a Continuous Emissions Monitor



According to EPA officials, CEMS that can measure certain pollutants, such as carbon monoxide, hydrochloric acid, nitrogen oxides, sulfur dioxide, and total organics, are commercially available and can meet requirements for regulatory purposes. Continuous opacity monitors are also commercially available and EPA has promulgated a performance specification for their use. In addition, EPA has proposed, but not yet promulgated, performance specifications for continuous measurement of multiple metals, particulate matter, and mercury.[4] CEMS that monitor multiple metals and particulate matter are commercially available in the United States, while mercury CEMS are available in Asia and Europe.

Predictive Emissions Monitoring Systems

Predictive emissions monitoring systems (PEMS) utilize data on operating parameters (such as temperature, pollutant flow rates, and oxygen levels) along with modeling software to predict emission levels. If predicted emissions remain below allowable levels, it is then assumed that actual emissions will remain under those levels. PEMS do not directly measure emissions as CEMS do, but they do provide a continuous indication of a facility's compliance status. According to EPA officials responsible for developing performance specifications, the agency allows the use of predictive systems to demonstrate compliance with certain nitrogen oxide regulations and the agency currently is developing a performance specification for generic PEMS use.

Leak Detection Instruments

At certain industrial facilities, such as petroleum refineries, fumes leaking from pipes and other equipment (often referred to as fugitive emissions) can account for a significant portion of overall emissions. EPA requires almost all refineries to implement leak detection and repair programs. Facilities that implement such programs must check for leaks using a portable hydrocarbon monitor and repair the leaks that exceed specified thresholds. Because of recent interest that government, industry, and environmental groups have shown in identifying lower cost leak detection programs, an EPA contractor recently prepared a report identifying alternative technologies that could drastically lower implementation costs.[5] Some of the reviewed technologies involved remote detection rather than use of portable monitors. The study found that annual costs of leak detection programs using traditional portable monitors ranged from

[4] According to EPA's Office of Air and Radiation, the mercury specification applies to municipal waste combustors, but not to coal-burning sources.

[5] See *Compendium of Sensing Technologies to Detect and Measure VOCs and HAPs in the Air*, *Final Report*, ICF, Inc., prepared for U.S. Environmental Protection Agency and the Equipment Leaks Project Team (June 1999). These technologies include Backscatter Absorption Gas Imaging, the Image Multi-Spectral Sensing Infrared Camera, Open-Path Fourier Transform Infrared Spectroscopy, Differential Optical Absorption Spectrometry, Tunable Diode Laser Absorption Spectroscopy, and Light Detection and Ranging.

$90,000 (for two small refineries) to $344,000 (for a large refinery), while the estimated annual costs associated with certain alternative technologies ranged from $9,600 to $41,000.

Figure 3 provides an overview of these advanced monitoring technologies.

Figure 3: Overview of Advanced Air Monitoring Technologies

Technology	How it works	Pollutants	Advantages	Disadvantages
Continuous emission monitoring systems (CEMS)	Continuously measures pollutants released by a source	Carbon monoxide, hydrochloric acid, mercury, multiple metals, nitrogen oxides, opacity, particulate matter, sulfur dioxide, and total organics	Considered highly reliable by regulators. Use has led to emissions reductions at regulated entities. Critical to success of emissions trading programs.	High purchase and operation costs relative to other monitoring options
Predictive emission monitoring systems (PEMS)	Predicts emissions using modeling software and data on operating parameters (e.g., flow rates, oxygen levels, and temperature)	Carbon monoxide, nitrous oxides, and sulfur dioxide	Cost less than CEMS to install and maintain	Difficult for software to account for all changes in process variables
Alternative leak detection devices	Detects pollutant leaks using various technologies, including remote detection	Volatile Organic Compounds and Hazardous Air Pollutants	Lower cost than traditional leak detection practices	Use of technologies may require regulatory changes

Extent to Which Improved Air Monitoring Technologies Are Being Used

We found that regulated facilities typically utilize advanced air monitoring technologies only when the regulations require them. While regulated entities have some incentive to use these technologies, such as the ability to optimize their processes, the fear that improved monitoring will reveal violations of clean air regulations often cancels out the incentives. While EPA generally requires facilities to maintain continuous compliance with air regulations, air emissions standards issued by the agency rarely require facilities to perform continuous monitoring due to time and resource constraints in issuing new rules, as well as the perception that available technologies are too expensive.

Most Use of Advanced Technologies Stems from Regulatory Requirements

EPA's Office of Air and Radiation reported that most advanced monitoring technology use stems from regulatory requirements. According to EPA officials, the most widespread requirements for using advanced monitoring technologies—specifically CEMS—stem from EPA's Acid Rain program. This program, established by title IV of the 1990 Clean Air Act Amendments, requires reductions of nitrogen oxide and sulfur dioxide emissions from electric utilities. The program also established an allowance trading system that permits electric utilities to trade sulfur dioxide allowances. The utilities must own enough allowances at the end of each year to cover the emissions from the affected units. The program currently affects over 2,300 electric utility units nationwide. Between 1990 and 1999, facilities participating in the program reduced their sulfur dioxide emissions by approximately 21 percent. EPA describes the use of CEMS to measure nitrogen oxide and sulfur dioxide emissions as critical to instilling confidence in the program and ensuring that emissions reductions are met.

A similar trading program, which the South Coast Air Quality Management District operates in Los Angeles, requires major sources to use CEMS to determine their nitrogen oxide and sulfur oxide emissions. This program has reduced the emissions of nitrogen oxides and sulfur oxides from participating facilities by about 17 and 6 percent, respectively, between 1994 and 1998. A recent program audit described CEMS as the most accurate and reliable method for direct determination of emissions. Lending further support to the importance of CEMS in the success of emissions trading programs, a recent National Academy of Public Administration study found that the lack of CEMS use in trading programs involving volatile organic compounds led to difficulty ensuring the certainty of emissions reductions.

Certain federal requirements not associated with trading programs also mandate CEMS use. For example, regulations that apply to some chemical plants, incinerators, petroleum refineries, pulp mills, and sulfuric and nitric acid plants require the use of CEMS. EPA has also required the use of continuous opacity monitors in regulations for a variety of combustion, materials handling, and smelting processes. EPA data show that at least 6,750 CEMS are used nationwide.[6] Approximately 80 percent of these are used to monitor carbon monoxide, opacity, nitrogen oxides, and sulfur dioxide. Less than 1 percent are used to monitor hydrocarbons and air toxics.

States also require advanced monitoring in certain circumstances. For example, a Pennsylvania official said that the state requires 445 CEMS in addition to 327 required by federal regulations. In addition, states can foster the use of advanced technologies by specifying the technologies that facilities can use to demonstrate compliance with certain regulations. For example, Texas allows regulated entities to use CEMS or PEMS to monitor compliance with certain regulations for nitrogen oxide emissions. A Texas official said that this has led to the use of more than 100 PEMS in the Houston area.

In addition, EPA and state agencies can, and sometimes do, require the use of advanced monitoring technologies as part of settlement agreements at facilities found noncompliant with air regulations. For example, in November 2000, EPA, the U.S. Justice Department, and the State of New York reached an agreement with an electric utility to resolve Clean Air Act violations. In addition to paying a $5.3 million civil penalty and reducing its emissions of nitrogen oxides and sulfur dioxide, the utility agreed to install advanced particulate matter continuous emission monitors.

Use of Advanced Technologies Can Lead to Cost Savings, Emissions Reductions, and Increased Compliance

In addition to their important role in emissions trading programs, advanced monitoring technologies can help facilities better understand their processes and identify opportunities to improve productivity and reduce waste. For example, a monitoring consultant described a magnesium casting company that monitored the loss of a sulfur compound (used to insulate molten magnesium) in its processes using CEMS.

[6] EPA officials said that this is the number of CEMS in use, not the number of facilities using them. EPA's compliance data administrator said that states voluntarily report CEMS use data and that the actual number of CEMS in use exceeds that reported.

Through a 4-hour test, the company identified opportunities for increased process efficiency that saved it hundreds of thousands of dollars per year because of increased efficiency and decreased loss of raw materials.

Use of advanced monitoring technologies can also help facilities avoid regulatory requirements. For example, an equipment vendor said that facilities sometimes voluntarily use improved technologies to demonstrate that their emissions remain below the thresholds that would otherwise categorize them as a major (rather than a minor) air pollution source. Such a demonstration allows these facilities to avoid the regulatory requirements associated with major source status.

In addition to the benefits that advanced monitoring technologies can provide regulated entities, their use in compliance monitoring has been associated with increased rates of compliance and emissions reductions. For example, a study conducted by EPA's Midwest regional office involving data from more than 1,100 facilities using advanced monitoring technologies, such as CEMS and continuous opacity monitors, found that (1) these facilities achieved a reduction in the number of instances where they reported excess emissions and (2) the use of these technologies resulted in emissions reductions.

Increased Chance of Identifying Violations Discourages Voluntary Use of Advanced Technologies

Voluntary use of advanced technologies by regulated entities is a double-edged sword. On the one hand, it may reap cost savings and other benefits. On the other hand, the technologies have the potential to reveal instances of noncompliance and violations that could lead to punitive action by EPA or interest groups. In particular, EPA officials told us that improved monitoring technologies could identify violations of emissions limits as well as the presence of pollutants that the regulated entity is not allowed to emit.

At a recent conference on air pollution monitoring technologies, a regulated entity and a monitoring consultant said that the "Credible Evidence" rule discourages the voluntary use of monitoring technologies. The Clean Air Act authorizes EPA to bring an administrative, civil, or criminal enforcement action "on the basis of any information available to the [EPA] Administrator." According to an EPA enforcement official, in promulgating the Credible Evidence rule in 1998, EPA sought to clarify the range of information that regulators and regulated entities could use in determining compliance with emissions limits. Importantly, this includes the use of information obtained through advanced monitoring technologies such as CEMS and PEMS.

According to an EPA enforcement official, the agency has attempted to mitigate these concerns about the voluntary use of monitoring technologies and has offered reduced penalties for facilities that self-disclose violations. In addition, EPA states in the rule's preamble that the agency focuses its judicial enforcement resources on large, significant cases rather than relatively minor matters. Specifically, it said that the agency focuses enforcement resources on violations that (1) may threaten or harm public health or the environment, (2) are of significant duration or magnitude, (3) represent a pattern of noncompliance, (4) involve a refusal to provide requested compliance information, (5) involve criminal conduct, or (6) allow a source to reap an economic windfall. The preamble also said that EPA does not intend to foster frivolous lawsuits, and that it does not expect that such lawsuits would result from the rule's adoption.

Despite this, many of those we interviewed conveyed a widespread belief that the rule continues to place emitters at risk for enforcement action. For example, a monitoring consultant said that the rule stands as a major barrier to more widespread voluntary use of advanced technologies, even though certain technologies can help identify process improvements that achieve cost and environmental benefits. He said that lawyers representing regulated entities are concerned that data gathered through voluntary monitoring could be used to show noncompliance. Similarly, a regulated entity said that the Credible Evidence rule stands as the single biggest barrier to performing voluntary monitoring with advanced technologies. EPA Office of Air and Radiation officials agreed that the potential for a facility to learn that it violates permit limits remains a major disincentive to continuous monitoring. They also said that regulated entities have little incentive to upgrade their monitoring technology and that improved monitoring will not occur without regulatory requirements.

Cost Concerns Also Hinder Use of Advanced Monitoring Technologies

For EPA to require the use of monitoring technologies, it must first develop approved test methods (for periodic or continuous monitoring) and performance specifications (for continuous monitoring). According to the Office of Air and Radiation, the development of performance specifications requires data from field tests, which they do not have the resources to conduct. Between 1995 and 2001, EPA's annual budget to develop, evaluate, and support emission testing and monitoring tools dropped from about $3,947,000 to $1,440,000; a 64 percent reduction.[7] As a

[7]Budget data were adjusted to account for inflation. All figures are in 2000 dollars.

result, EPA must rely on outside parties to provide the necessary data. However, because EPA does not always participate directly in the testing, the results may not be suitable for regulatory purposes. The official said that EPA is still "feeling its way" through its reliance on data from external parties. An EPA official said that information gathered through the agency's ETV program can sometimes assist in developing performance specifications and test methods.

In accordance with Executive Order 12866 and the Unfunded Mandates Reform Act of 1995, EPA analyzes the costs, benefits, and alternatives to, certain proposed regulations. However, according to an EPA air program official, the agency does not have formal cost-benefit criteria for use in selecting the compliance monitoring requirements that will accompany new rules. This official and another EPA air official who commented on a draft of this report said that the agency evaluates the costs of different compliance monitoring options, and that agency staff use their judgment to determine whether certain options impose excessive costs on affected sources.

The first official also said that when EPA promulgates many of its rules, such as Maximum Achievable Control Technology regulations for certain emitters of air toxics, it determines the level of pollution control that facilities can achieve using available technologies.[8] It then generally requires the affected facilities to control their emissions at certain levels and monitor their compliance using the test method EPA used when it originally tested facilities; in most cases, stack tests. While EPA's preference is for facilities to continuously monitor their compliance, EPA officials said that, given the time and resource constraints associated with the issuance of air quality regulations, the agency has decided not to spend resources to evaluate alternative compliance monitoring options. EPA's Office of Air and Radiation said that the agency encounters less resistance from industry when promulgating rules if it requires compliance monitoring via the test method that the agency used to set the standard.

EPA air program officials also expressed concern over the reaction of the Office of Management and Budget (OMB) to requirements to use advanced technologies. They maintained that OMB generally views monitoring

[8] The Clean Air Act specifies the methodology for determining the level of pollution control that affected facilities must achieve to comply with Maximum Achievable Control Technology standards.

requirements as a cost rather than a benefit, and that taking such requirements out of rules can reduce drastically the overall costs to industry. An EPA enforcement official said that, in promulgating rules, the agency often has to compromise with OMB, and drops the monitoring requirements as a result; despite the fact that emissions reductions have been achieved at facilities required to use advanced monitoring technologies. According to EPA's Office of Air and Radiation, the agency has yet to conduct a cost-benefit analysis to evaluate the advantages of using CEMS rather than higher levels of control devices to achieve marginal emissions reductions.

A monitoring consultant disagreed with the perception that CEMS cost too much for facilities to use, stating that EPA's requirements for daily equipment calibration adds to the cost of CEMS. An EPA air program official said that the agency's data quality and daily calibration requirements provide certainty of facility emissions, which he views as critical to the integrity of emissions trading programs. The monitoring consultant estimated that the average capital cost of a CEMS for facilities participating in the Acid Rain program—including daily calibration—ranged between $150,000 and $200,000, with annual operating costs of $50,000. Similarly, an industry group estimated in 1998 that the total capital investment for a nitrogen oxide CEMS similar to those used in a California emissions trading program would range between $71,500 and $127,500, and that the total annual cost of owning and operating the system would be approximately $24,000 to $38,000.

The consultant said that regulated facilities not participating in trading programs could lower the costs of continuous monitoring if they had less rigorous calibration requirements. He said, for example, that facilities in Germany perform tests to determine how often the equipment needs calibration, and then work with the regulatory agency to arrive at an agreed-upon calibration schedule. In some cases, facilities only need to calibrate their equipment monthly. The consultant suggested that disseminating information on the true costs of CEMS would demonstrate that they are not as expensive as believed, thereby making it easier for EPA to require their use. For example, he stated that simple systems used in Canada and Norway cost between $30,000 and $50,000.

Thus, there may well be situations where the costs of CEMS are lower than perceived, and in fact are lower than their potential benefits. There may also be ways in which EPA itself could lower CEMS' costs by, for example, adjusting its requirements for daily equipment calibration at facilities that do not participate in trading programs. We believe such situations can best be identified through systematic cost-benefit analysis.

Conditional Approval of Alternative Methods Can Foster Use of Advanced Technologies

While regulated facilities must adhere to EPA's approved test methods and performance specifications, EPA will conditionally approve alternative methods that still meet the agency's data requirements, and sometimes receives and approves requests to use advanced monitoring technologies. For example, in 2000, the agency approved a request to use a PEMS for compliance monitoring at an industrial boiler.

Between June 1996 and November 2000, EPA received 115 requests to use alternative methods. Of these, 54 were approved, 3 were denied, and 2 were later withdrawn by the submitter. Approximately 83 percent of the approvals were issued in less than six months. An EPA official said that the remaining submittals were either (1) never listed in the agency's database as an approval or disapproval, (2) lacked additional information requested of the submitter, or (3) were determined not to be an alternative test method or monitoring request under federal regulations.

According to the president of a monitoring company, conditional approval does not necessarily lead to the widespread acceptance of promising technologies. He discussed the time, cost, and limited benefit associated with conditional approval of alternative methods. He cited the example of a technology that monitors volatile organic compounds and hazardous air pollutants using gas chromatography and mass spectroscopy. The device, which costs between $60,000 and $80,000 provides results about every ten minutes. He said the manufacturer has spent millions of dollars developing the technology and between $300,000 and $400,000 trying to get EPA approval. He said that he could not get EPA to identify a testing protocol to demonstrate the technology's equivalency to the approved method, so his company designed its own. EPA accepted the protocol, but was still hesitant to approve the technology even after it met the testing requirements. After the manufacturer contacted one of its Members of Congress, who in turn contacted the EPA Administrator, EPA finally offered conditional approval. He described this outcome as "totally unacceptable" because it required the manufacturer to request approval from the relevant state agency or EPA each time a facility wants to use the technology. He said that state agencies, which implement clean air programs, generally prefer for regulated entities to use methods that have more widespread acceptance by EPA.[9]

Factors That Influence Development of New Air Monitoring Technologies

The presence or absence of regulatory requirements not only influences the use of existing technologies, but also the research and development of new technologies. An equipment manufacturer and regulators said that without regulatory requirements, manufacturers have little incentive to bring new technologies to market. As a result, more of the research and development burden falls to government agencies, which generally can devote limited resources to this purpose.

Lack of Regulatory Requirements Discourages Development of New Technologies

In 1995, EPA's Science Advisory Board characterized the use of CEMS for measuring air toxics as a problem of what must come first: the regulatory mandate for CEMS that drives the market or commercially available CEMS that allow regulators to mandate their use. The Board said that EPA must have the confidence that a technology can fulfill the agency's needs before it can write a rule requiring its use. It also noted that instrument developers and manufacturers were unlikely to conduct the expensive research and development required to make technologies available unless EPA mandated their use. The Board suggested that EPA try to break the deadlock and recommended that EPA identify all of the barriers to the availability of commercial, cost-effective CEMS and address them in a systematic manner. Officials in EPA's research and development office said that the development and implementation of advanced emissions monitoring technologies has no clear starting point. EPA's Acid Rain program suggested that a cost-benefit analysis would be a logical first step.

In a similar vein, equipment manufacturers and regulators told us that regulatory requirements define the market for advanced monitoring technologies, such as CEMS. An industry consultant said that equipment developers seldom pursue new technologies unless they see the potential for a regulation that would require monitoring. He noted that, a developer who saw an opportunity would try to determine the size of the market and the number of monitoring units that will be needed. It will then evaluate the competition and try to estimate its potential share of the market. After

[9] EPA's Office of Air and Radiation said that the device does not satisfy the data collection requirements necessary to obtain approval as an alternative to an EPA test method. However, EPA also said that the device collects data often enough to meet CEMS performance specifications, for which no EPA approval would be necessary.

evaluating this information, it will seek to determine the appropriate level of investment the opportunity justifies. As an example, he said that several companies which have recently developed particulate matter monitoring technologies face significant financial risk if EPA delays or decides not to impose monitoring requirements as part of its new particulate matter rules.

EPA officials said that technologies exist to monitor most of the pollutants that are not monitored, and that additional monitoring of these pollutants does not require “leaps of science.” Similarly, a representative of an equipment industry trade association stated that “if regulations are imposed, the technology will follow.” He also said that the trade association had once asked its members for case study examples of their new technologies and most had responded that they did not pursue new technology without a potential or existing market. An equipment vendor said that most improvements involve incremental changes that lower costs and enhance performance.

EPA and Other Federal Agencies Perform Limited Research and Development

The lack of incentives for private research and development leaves some of the burden on government. According to agency officials, EPA devotes a limited amount of funding to the development of advanced monitoring technologies, but this focuses on supporting agency research objectives, such as improving the scientific understanding of pollutants, rather than bringing promising technologies to market. For example, we interviewed an official in EPA’s Office of Research and Development who is pursuing a technology that measures air toxics, such as dioxin. The official described this technology as providing versatile measurement —in terms of the range of pollutants detected and the levels at which it detects them—and as a significant advance in monitoring technology, but it would take an additional $5 million to make this technology commercially available. Given EPA’s resource constraints, the funds would have to come from the private sector. In fiscal year 2001, EPA devoted $247,900 to the research and development of point source air monitoring technologies, such as CEMS. The official stated, however, that the lack of regulatory requirements and the high cost of bringing technologies to market make the research and development of this and other technologies a very risky venture for equipment manufacturers.

According to EPA’s Office of Research and Development, the agency’s ETV program can assist in overcoming the barriers to the introduction of new monitoring technologies developed by the private sector. As of June 2000, ETV had completed performance testing or verification of over 30 air monitoring technologies, including mercury and multiple-metals CEMS, particulate matter monitors, and portable nitrogen oxide analyzers.

Other federal agencies, including the Department of Energy (DOE) and Department of Defense (DOD), also research and develop monitoring technologies. DOE targets its efforts on the continuous monitoring of pollutants, including mercury, arsenic, and lead, at contaminated DOE sites. Through its Strategic Environmental Research and Development Program, DOD develops improved monitoring tools for environmental compliance. For example, DOD has developed a laser technology that allows near-real-time in-stack analysis of a range of metal and gas pollutants. An EPA official said, however, that the research and development performed by external parties, such as DOD, does not always provide results that are acceptable for regulatory purposes.

Conclusions

The compliance monitoring that stationary air pollution sources perform varies considerably. As a result, regulators and regulated entities sometimes lack certainty about whether air pollution sources maintain continuous compliance with clean air regulations.

Advanced monitoring technologies, particularly CEMS, can provide facilities with information that enables them to improve the efficiency of their processes, thereby reducing emissions and providing cost savings. EPA officials consider CEMS to provide the greatest certainty of a facility's emissions. In addition, EPA data show that use of advanced technologies correlates with emissions reductions at regulated entities.

However, there are powerful disincentives to the voluntary use of technologies. Among the greatest disincentives is EPA's Credible Evidence rule, which enables the use of data derived from use of advanced technologies as the basis for enforcement actions. EPA has indicated that it does not plan to use this rule in cases of minor violations identified through the use of these technologies. Nonetheless, EPA air program officials and others that we interviewed conveyed a widespread belief that the rule continues to place emitters at risk for enforcement action. Largely as a result of these concerns, emitters generally use advanced monitoring technologies in circumstances in which they are required to do so by regulations, such as the requirements for CEMS use at facilities participating in the Acid Rain program.

An additional disincentive for the wider use of CEMS is the perception that CEMS' costs are unacceptably high. However, EPA does not regularly evaluate the costs and benefits of alternative compliance monitoring options. Such an evaluation would involve analyzing data on (1) the costs of purchasing and operating monitoring equipment, taking into consideration different equipment calibration and performance requirements, and (2) the benefits of using these technologies, such as their value in facilitating emissions trading programs, as well as the ability to achieve increased compliance and emissions reductions.

Recommendations

We recommend that the Administrator, EPA, direct the agency's Office of Air and Radiation, to develop a strategy that would address the barriers that impede wider use of advanced monitoring technologies. As a part of this strategy, EPA should:

- Identify ways to alleviate the widespread view among emitters that it will use the Credible Evidence rule in enforcement cases where voluntary use of such technologies may reveal minor violations.
- Undertake an analysis of the costs and benefits associated with different compliance monitoring options in a manner that would help to identify additional opportunities for the expanded use of advanced monitoring technologies.

Agency Comments

EPA's Office of Air and Radiation provided comments on the material covered in this chapter. The Office said that, overall, we accurately covered the issues and reached fair conclusions. The comments provided were generally editorial or intended to clarify the material presented, and we incorporated them as appropriate. For example, we added text to clarify that EPA's approved methods and performance specifications for monitoring individual pollutants do not apply to all types of regulated entities or industrial air pollution sources.

EPA's Office of Research and Development provided comments from several individuals responsible for the development and validation of monitoring technologies. These comments covered a wide range of issues, but generally suggested that we (1) clarify our definition of "advanced" monitoring technologies, (2) more comprehensively discuss several issues relating to the development of new monitoring technologies, and (3) enhance our discussion of the role that the agency's ETV program can play in addressing barriers to the introduction of new monitoring technologies.

Regarding (1), we clarified that our discussion of advanced monitoring technologies focuses on those that can improve regulated entities' ability to monitor their compliance with air regulations. Regarding (2), the Office of Research and Development suggested that we more comprehensively discuss the available monitoring technologies, the improvements that are necessary, and the benefits of improved monitoring. We believe that it was limited in the level of detail the report should devote to these matters by the enormous range of technologies that address air monitoring and the need to devote sufficient attention to the legal and regulatory barriers inhibiting wider use and development of such technologies, which was the primary focus of the report. Regarding (3), we expanded our discussion of ETV as it relates to the development of performance specifications and test methods, as well as to bridging the gap between commercial availability of technologies and their use for regulatory purposes. We also made suggested editorial changes where appropriate.

EPA's Office of Enforcement and Compliance Assurance did not provide comments on the material covered in this chapter.

Chapter 3: Technologies for Measuring Wastewater Discharges

For decades, wastewater treatment plants and industrial facilities have been required to monitor the concentrations of pollutants in their wastewater. Consequently, technologies have been developed to measure hundreds of pollutants of interest. Many of these technologies, however, are over 15 years old. A number of newer technologies can monitor pollutants in a manner that is more cost-effective and/or more accurate than those that are currently in use. However, because EPA has not approved these technologies for monitoring compliance with wastewater discharge permits, they are not widely used for this purpose.

EPA is quick to approve requests to use alternative methods intended for use by a single entity, and has significantly expedited its response time in reviewing minor modifications to existing methods. However, a lengthy and cumbersome approval process has served as a major disincentive to equipment manufacturers seeking to develop innovative monitoring technologies with nationwide application. EPA has tried to address the problem through a streamlined "performance-based" approval process, but the agency has not implemented this process because it has not resolved all the issues impeding its use.

Monitoring Wastewater Discharges Under the Clean Water Act

As noted in chapter 1, a Clean Water Act program requires regulated facilities to monitor their wastewater discharges to ensure their compliance with pollutant discharge limits. Currently, there are about 96,000 facilities that are regulated under the act's pollutant discharge program. Of these, about 6,600 discharge in quantities sufficient enough to be deemed "major" dischargers. These facilities include (1) sewage treatment facilities with a design discharge daily flow greater than one million gallons of effluent—a mix of domestic and industrial wastewater, (2) certain classes of industrial facilities, and (3) industrial facilities that discharge a certain amount or concentration of pollutants. In general, major dischargers may be required to report the quantity and content of their discharge to EPA or a state regulatory agency on a monthly basis, although they may monitor their effluent on a daily or more frequent basis. Other dischargers may monitor and report on a less frequent basis. Table 3 identifies the industrial facilities that discharge the greatest quantity of conventional and toxic pollutants.[1]

[1] Conventional pollutants include those typically found in municipal sewage, such as fecal coliform bacteria, oil and grease, and pH. Toxic pollutants include metals and manmade organic compounds.

Table 3: Industrial Sources of Conventional and Toxic Pollutants

Source Category	Quantity of Discharges (in tons)	Proportion of Total (percentage)
Coal Mining	1,069,764,866	85
Primary Metal Industries	128,853,898	10
Electric, Gas, and Sanitary Services	39,448,827	3
Other*	21,190,169	2
Total	**1,259,257,760**	**100**

Note: Other includes more than 70 individual source categories.

Source: EPA

While the monitored pollutants and the frequency of the monitoring may vary among regulated facilities, regulated entities must use EPA-approved test methods. Test methods describe the analytical procedures for measuring the presence and concentration of pollutants. In promulgating guidelines for its test methods, EPA has issued regulations that reference specific test methods and, in some cases, the actual text of a test method.

Since the 1970s, EPA and consensus standards organizations, such as the American Society for Testing and Materials, have developed most of the currently approved 710 test methods for the monitoring of over 400 pollutants.[2] (Examples of test method categories are summarized in table 4.) In addition, EPA allows the regulated community, instrument manufacturers, and other entities to apply for agency permission to use an alternative test method in the place of an EPA-approved method. According to EPA, these alternative test methods are either modifications to approved test methods or new test methods. Applicants seek approval for an alternative test procedure when the alternative procedure improves some aspect of method performance, such as reducing analytical costs, improving laboratory productivity, or reducing the amount of hazardous materials used in the laboratory.

[2] Consensus standards organizations include groups such as the American Society for Testing and Materials and the publishers of *Standard Methods for the Examination of Water and Wastewater*. These organizations develop voluntary consensus standards for monitoring through the participation of all interested stakeholders, including producers, users, consumers, and representatives of government and academia.

Table 4: Examples of EPA Test Method Categories

Test Method Category	Pollutant Measured	Technology/Instrument Used
Biological methods	Bacteria (fecal coliform)	Human observation of bacteria present
	Aquatic toxicity	Human observation of fish mortality rates
Inorganic methods	Oil and grease	Hexane extraction and gravimetry
	Nitrate	Colorimetric
	Metals	Graphite furnace atomic absorption
Non-pesticide organic methods	PCBs	Gas chromatograph/mass spectrometer
	Dioxin	Gas chromatograph/mass spectrometer
Pesticide methods	Pesticides (e.g., DDT)	Gas chromatograph/mass spectrometer

Source: Title 40, Code of Federal Regulations, Part 136

Available Technologies That Can Improve Wastewater Monitoring

According to EPA, improvements in instrumentation, the quality of test methods, and the number of laboratories capable of performing analyses for environmental monitoring have grown substantially since the 1970s. However, according to officials with EPA and other organizations that we interviewed, while many methods exist to measure pollutants in wastewater, approximately one-third of EPA-approved methods are over 15 years old.

In a 1988 report to the Congress on the availability of monitoring technologies and methods, EPA cited several examples of new technologies that could exceed the performance of existing methods in terms of better sensitivity, lower cost, and more reliable identification of regulated pollutants.[3] For monitoring inorganic pollutants, EPA cited two technologies—inductively coupled plasma/mass spectrometry (ICP/MS) and ion chromatography—that could (1) decrease the cost of analyses, (2) increase laboratory productivity and the quality of the analytical data, and (3) lower the effective detection limits in a wide variety of samples. Other experts we interviewed, including representatives of consensus

[3] *Availability, Adequacy, and Comparability of Testing Procedures for the Analysis of Pollutants Established Under Section 304(h) of the Federal Water Pollution Control Act*, Report to Congress, Office of Research and Development, EPA (EPA/600/9-87/030. Sept. 1988).

standards boards, state regulatory agencies, regulated entities, and commercial laboratories, also cited these two technologies as among the most significant improved technologies available.

Inductively Coupled Plasma/Mass Spectrometry

Inductively coupled plasma/mass spectrometry (ICP/MS) is used to measure inorganic elements (e.g., metals) and provides significant improvements over currently approved technologies in terms of lower detection levels and reduced cost per sample. The ICP/MS first became commercially available in the early 1980s and has been continuously improved, according to one manufacturer we interviewed. A 1988 EPA report recognized the potential improvement offered by ICP/MS, stating that "in the next decade, the application of inductively coupled plasma/mass spectrometry to environmental analyses could result in the single greatest impact on the analysis of metals." An ICP/MS instrument currently costs between $150,000 and $200,000, according to one manufacturer we interviewed.

An ICP/MS can detect the concentrations of pollutants down to the parts per trillion range, while a comparable technology approved by EPA (i.e., a graphite furnace) can only detect down to parts per billion. Measuring to such levels is important when regulated entities are discharging to waters that are impaired by certain pollutants. For example, in cases where certain waters are impaired by mercury or lead, the regulated entities discharging to these waters must reduce their discharges of these pollutants to very low levels (i.e., lower than what is normally required). In its 1988 report, EPA specifically recommended that efforts to develop ICP/MS test methods consider monitoring toxic metals at low concentration levels.

An additional key benefit of the ICP/MS is that it can rapidly analyze multiple elements in a single sample, as opposed to many current EPA-approved test methods, which use technologies that analyze only one element at a time. Accordingly, the ICP/MS can reduce costs to users such as commercial laboratories or large sewage treatment plants that test numerous samples. Representatives of one wastewater treatment plant told us that using the ICP/MS could reduce their analysis costs by about 20 percent below the cost of current EPA-approved methods.

Ion Chromatography

Ion chromatography is used to measure inorganic substances, such as nitrates and phosphates. Like the ICP/MS, it can reduce costs incurred by facilities that must process and analyze numerous samples. Furthermore, EPA recognized ion chromatography's potential in its 1988 Report to Congress, calling it an important technology that would become more routinely used for monitoring pollutants in the future. This technology was first commercially available in the mid-1970s and currently costs between $14,000 and $60,000, according to one manufacturer we interviewed.

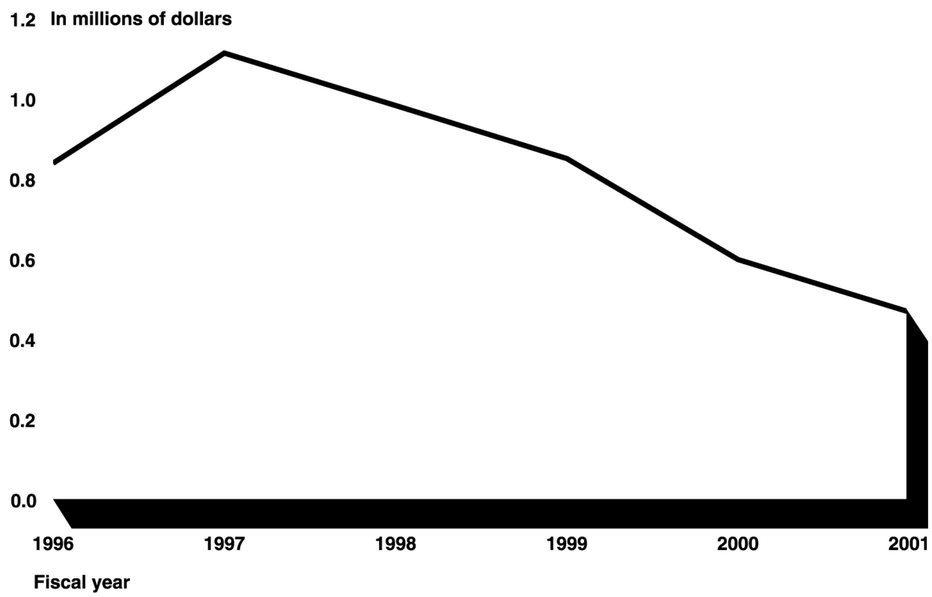
The major benefit of ion chromatography is that it can rapidly analyze multiple pollutants in a single sample, as opposed to current EPA-approved methods for wastewater monitoring that analyze one pollutant at a time. As a result, ion chromatography can reduce costs to users, such as commercial laboratories or large sewage treatment plants that test numerous samples. In addition, ion chromatography can detect levels of pollutants in the parts-per-billion range, which is considerably more sensitive than current EPA-approved test methods for wastewater.

Extent to Which Improved Wastewater Monitoring Technologies Are Being Used

Representatives of the commercial laboratories we interviewed said that they routinely use ICP/MS and ion chromatography to monitor pollutants regulated under the Safe Drinking Water Act (these technologies are approved for use in this program). However, according to EPA officials, the majority of regulated entities do not use these technologies for compliance monitoring under the Clean Water Act because EPA has yet to formally approve them for that purpose. Since regulated entities may only use an approved monitoring method, a facility could be found in noncompliance if it uses an unapproved technology or method.

EPA proposed approving the use of ICP/MS and ion chromatography for wastewater compliance monitoring in the mid-1990s. However, agency officials noted that funding constraints prevented them from performing additional validation studies, which were needed to demonstrate the reliability of the ICP/MS method for use in wastewater monitoring (additional studies were not needed for the ion chromatography method, but EPA is waiting to promulgate these methods as a single rule). They pointed in particular to the over 50 percent decline in funding devoted to method development and validation over the past 4 fiscal years (see fig. 4). According to these officials, this area lost much of its funding when resources were shifted to other priority activities, such as the development of effluent limitations and guidelines with court-ordered deadlines. Because of these delays, EPA's Office of Water has authorized regional offices, upon request, to give approval to any facility that requests to use either the ion chromatograph or ICP/MS method. To date, four regional offices have requested this authority.

Figure 4: EPA's Office of Water Method Development Budget for Wastewater Monitoring



Note: In constant dollars, base year 2000.

Source: EPA

Factors That Influence Development of Improved Wastewater Monitoring Technologies

EPA is quick to approve methods intended for use by a single entity, and has significantly expedited its response time in reviewing minor modifications to existing methods. EPA's recent changes to streamline its approval process were viewed very favorably by two instrument manufacturers who had recently been through the process. However, EPA's review process for major modifications or new methods developed by outside organizations for nationwide use remains time-consuming and discourages some manufacturers from pursuing innovations for wastewater monitoring. EPA has acknowledged the problem and proposed a "performance-based" approval process, but has not implemented this process due to unresolved issues within the agency.

EPA's Approval Process for New or Modified Test Methods

Until the mid-1990s, EPA usually initiated work on all new test methods used in monitoring wastewater compliance. EPA maintained a program for organizations outside the agency to apply for the approval of major or minor modifications to existing EPA methods. However, EPA officials associated with the program, and organizations that went through its process, described it as lengthy and hard to use. Furthermore, EPA recognized in 1996 that the requirement to use prescriptive test methods and technologies had unintentionally imposed a significant regulatory burden and created a barrier to the use of innovative environmental monitoring technology.

To encourage the development of new and innovative technologies by outside organizations, and to expedite approval of major or minor modifications to existing EPA methods, EPA revamped its process for approving methods developed by outside organizations for wastewater compliance monitoring. EPA's process requires varying levels of validation, review, and approval of proposed methods, depending on the method's intended use (use by only the applicant as opposed to use by any monitoring entity).[4] The organization submitting a proposed method is responsible for conducting the necessary validation studies. EPA reviews the results of these studies to determine the applicability and performance of a proposed method before making an approval decision. In general, the process requires organizations to perform more testing if they are proposing more significant changes and/or a method for nationwide use, rather than simply for use by an individual facility. Table 5 highlights the varying levels of validation and approval required for different types of proposed methods.

[4] The most recent guidelines are found in *Protocol for EPA Approval of Alternate Test Procedures for Organic and Inorganic Analytes in Wastewater and Drinking Water* (March 1998) and *Protocol for EPA Approval of New Methods for Organic and Inorganic Analytes in Wastewater and Drinking Water* (March 1999).

Table 5: Validation and Approval of Proposed Methods

Type of Proposed Method	Intended Users	Level of Validation Required	Type of Approval
Minor Modifications (for very minor modifications to EPA approved methods)	Applicant only or anyone	Little or no formal validation	Approval by EPA Headquarters through approval letter
Limited Use (for both major modifications to EPA approved methods and for new methods)	Applicant only	1 lab validation study	Approval by EPA Regional Office through approval letter (may consult with EPA Headquarters)
Nationwide Use (for both major modifications to EPA approved methods and for new methods)	Anyone	3 to 9 lab validation study	Approval by EPA Headquarters through formal rulemaking

Source: GAO analysis of EPA's process

Minor Modifications. While proposals for minor modifications are not likely to result in major improvements for users, commercial laboratories and equipment manufacturers depend on EPA approval. According to one EPA official, older EPA approved methods are very specific. They may prescribe, for example, the size of glassware (e.g., a 100-milliliter beaker) that must be used when performing the test method. This official noted that in some instances, state compliance officials have questioned minor deviations that commercial laboratories have made from these methods. As a result, laboratories have had to submit applications to EPA seeking approval for very minor modifications. In addition, as one equipment manufacturer noted, potential buyers are reluctant to use any monitoring methods for compliance purposes that have not been certified by EPA out of fear that they may be found in noncompliance with their wastewater monitoring requirements.

Limited Use. Unlike applications for minor modifications, proposals for limited use applications—those for use by a single entity—are for significant changes to existing EPA-approved test methods or entirely new methods. According to EPA, the "limited use" distinction is used primarily by regulated facilities, commercial laboratories, or other entities that routinely monitor samples from the same site or sites. However, EPA only allows the facility or laboratory that applies for a limited-use approval to use the test method. Consequently, EPA does not require these applicants to perform extensive validation studies involving multiple laboratories.

Nationwide Use. In contrast to applications proposing minor modifications or changes for which use is limited to a single facility, proposals for new methods or major modifications intended for nationwide use have a greater potential to affect the entire regulated community because these methods, if approved, will be available for nationwide use. Consequently, EPA requires nationwide-use applications to undergo a validation study in which the performance of the proposed method is verified by three to nine independent laboratories. If necessary, EPA may ask applicants to revise their proposed methods before deciding that a method is acceptable.

In addition to the technical review—the process by which EPA examines an application and determines the applicability and performance of a proposed method—EPA requires all new methods or major modifications intended for nationwide use to go through the rulemaking process. During the rulemaking process, a method is published as a proposed rule in the *Federal Register*, public comments are received and addressed, and the method is published as a final rule.

EPA Has Streamlined Its Process for Approving Minor Modifications

Our analysis of EPA data for applications for minor modifications—including 40 applications submitted between fiscal years 1993 and 2000—shows that EPA took an average of about 1.4 years to review and issue a decision. However, the timeliness of EPA's responses has improved significantly in recent years. For example, agency data show that it took an average of 4.5 months to reach a decision on applications received during fiscal year 1999, the last year for which complete data are available. Two equipment manufacturers that recently went through EPA's approval process substantiated the process' expedited response time. They noted that, as a result of the changes made to the approval process by the agency, EPA's performance improved substantially during the past few years.

EPA data show that the agency's quickest response time came when reviewing and issuing an approval decision for limited-use applications. Our analysis of EPA data for 26 limited-use applications submitted between fiscal years 1993 and 2000 shows that EPA took an average of about 4 months to review the applications (including reviewing the results of the required single-lab validation study) and to issue a decision.

While EPA has received considerable praise for its improved performance in processing proposals for minor modifications, this improvement may be short-lived, according to both the agency officials and potential applicants we interviewed. In fiscal years 1999 and 2000, EPA supplemented its own staff resources with an allocation of $75,000 per year for a contractor to perform reviews and assist in administrative duties. However, in fiscal year 2001, no such funds have been provided because all available contract dollars are being used to fund programs that directly support court-ordered deadlines and schedules. Instead, the agency is performing all work with internal resources equivalent to one full-time staff person. EPA officials acknowledge that this funding cut will slow the approval process down, and two equipment manufacturers we interviewed expressed concern that the program may cease to function altogether.

Nationwide-Use Methods Are Hindered by Lengthy EPA Approval Process

While EPA has improved its process for approving minor modifications, its approval process for the most promising methods—those involving major modifications or new monitoring methods with nationwide application—continues to be time-consuming. Our analysis of EPA data on nationwide use applications shows that between fiscal years 1993 and 2000, EPA approved two nationwide use methods out of the total 101 applications it received.[5] It took about three years for one of the approved methods to go through both the EPA technical review process and the formal rulemaking process, while the other method took about 3.6 years.[6] In a third case that is currently going through the rulemaking process, the sponsor projects that it will take a total of 5 years before the method would be approved and published as a final rule. A wide variety of the organizations that we interviewed, including state regulatory authorities, regulated entities, and equipment manufacturers, expressed concern over EPA's lengthy approval and rulemaking process.

The National Water Quality Monitoring Council, a federal advisory committee, has voiced similar concerns about EPA's approval process. In a 1999 position paper on environmental monitoring, the Council stated

[5] Of the other 99 applications received for nationwide use, 8 were disapproved, 3 were cancelled by the applicant, 16 were closed by EPA, 2 were not sent to the proper state or EPA Regional authority, 42 are awaiting additional data from the applicant, 26 are still under review by EPA, and 2 are awaiting rulemaking.

[6] The length of time to obtain EPA approval cannot be solely attributed to EPA's technical review or the rulemaking process. For example, 42 applications are awaiting action by the applicant.

that, “Due to current bureaucratic and administrative constraints, it is time consuming, resource intensive, and cumbersome to modify existing methods or add new improved methods to the Federal Register. The result is that more sensitive, less expensive, faster, or more modern methods—developed either by federal agencies or consensus organizations—have not been easily implemented or encouraged in compliance or ambient monitoring.”[7]

According to the EPA officials that we interviewed, the requirements of the rulemaking process prolong the agency’s timeframes for approving nationwide-use methods. EPA officials estimated that the rulemaking process—which includes proposing a rule in the Federal Register, receiving and responding to comments on the proposed method, sending the final rule through EPA’s internal review process (which includes a review by the Office of General Counsel), and publishing the final rule—can take from 1 to 3 years. Another factor contributing to the length of the process is EPA’s shift of resources away from the development and approval of innovative test methods to other priority activities, such as development of effluent limitations and guidelines with court-ordered deadlines. As noted previously, EPA funding to support the approval process for methods developed by outside organizations was eliminated in fiscal year 2001.

Competing priorities within the EPA Office of Water are not the only problem. Other EPA offices also have to prioritize their work, which can slow down the approval of test methods. For example, an EPA official told us that higher priorities in the Office of General Counsel have left an ICP/MS method waiting 6 months for review—an essential step before it can be issued as a final rule.

In light of these difficulties, several equipment manufacturers who have been through EPA’s approval process, told us that EPA’s lengthy approval process has dissuaded them from pursuing both EPA approval of new wastewater monitoring methods and significant modifications to existing ones. For example, one equipment manufacturer told us that his company may only have a limited time to recoup its investments in patented technologies once they are finally approved for use. This manufacturer pointed out that, by the time EPA approves its technology for nationwide

[7] Methods & Data Comparability Board, National Water Quality Monitoring Council, position paper on a Performance-Based Measurement System.

use, his company will only have 4 years left on its 17-year patent to exclusively manufacture its technology.

Two manufacturers spoke of opportunities to introduce innovative monitoring technologies that had been frustrated by the approval process. One noted that his company had invested in the development of "clean" monitoring methods that, unlike many current approved methods, do not require the use of toxic materials in analyzing samples. Another cited a monitoring technology that is already approved for drinking water monitoring. In each case, however, the sponsors said that the lengthy approval process deterred them from seeking EPA approval. These manufacturers also told us that they have chosen to pursue the sales of their monitoring technologies in other markets. For example, one manufacturer told us that she prefers to sell her equipment in the more profitable pharmaceutical market. Another manufacturer told us that he prefers to invest in developing new methods for the biotechnology or pharmaceutical monitoring market rather than the environmental market.

In addition, two of the equipment manufacturers that we interviewed said that they are also focusing more of their attention on overseas markets. This tendency is consistent with the findings in the 1998 U.S. Department of Commerce report, which observed that "U.S. environmental instrument manufacturers have generated over half of their revenues from outside the United States since 1994."

EPA Recognizes the Problem but Has Yet to Implement a Solution

Since the mid-1990s, EPA has recognized the need to streamline its approval process to decrease the amount of time and agency resources required to approve new and modified test methods. According to EPA, "Because advances in analytical technology continue to outpace the capacity of [the Office of Water's] method approval program, the program has been under-utilized and slow to respond to emerging technologies."[8] EPA made changes to streamline its process in 1995, which improved its response time in approving minor modifications to existing methods, but the approval of major modifications and new methods for nationwide use still remains problematic. EPA proposed a plan in 1997 to implement a performance-based system for environmental monitoring in all of its programs, to the extent feasible, which would address some of these

[8] *Protocol for EPA Approval of New Methods for Organic and Inorganic Analytes in Wastewater and Drinking Water* (March 1999).

continuing problems.[9] Such a system would convey "what" needs to be accomplished (i.e., what information a test method should yield), but not prescriptively convey "how" to do it.

To implement such a system, EPA stated that it would specify what questions the measurement must answer, what decisions the resulting data are to support, what level of uncertainty is acceptable for making the decisions, and what documentation is required. EPA would specify performance criteria for the measurements, and data producers would be required to demonstrate that their proposed test method meets these criteria.[10] According to EPA, such a performance-based approach would provide the regulated community more flexible and less costly approaches to conducting required monitoring, and importantly, would expedite the use of new and innovative technologies.

A large number of the organizations we interviewed—including representatives from equipment manufacturers, state regulatory agencies, regulated entities, commercial laboratories, and consensus standard organizations—said that EPA should adopt a performance-based approach to environmental monitoring. According to one equipment manufacturer, a change to a performance-based approach would be the single most important thing that EPA could do to improve its approval process. However, many of these organizations also said that EPA might have problems implementing such a system.

This concern was echoed in our discussion with EPA enforcement officials. Officials within EPA's Office of Enforcement and Compliance Assurance told us that under a performance-based system, regulated facilities would be able to use new or modified test methods without having to obtain an official review by EPA officials with the requisite technical skills. They claimed that a performance-based system places extra demands on federal and state inspectors to determine whether alternative monitoring methods are technically acceptable. They also told us that a performance-based system would make it harder to litigate cases

[9] EPA notice in *Federal Register*, vol. 62, no. 193, Oct. 6, 1997. EPA defines a performance-based measurement system as a set of processes wherein the data quality needs, mandates, or limitations of a program or project are specified, and serve as criteria for selecting appropriate methods to meet those needs in a cost-effective manner.

[10] According to EPA, performance characteristics can include parameters such as detection limits, precision, accuracy, analysis time, and analysis cost.

against facilities, since the validity of new or alternative methods would have to be established in court.

According to officials in EPA's Office of Water, the performance-based approach in approving wastewater-monitoring technologies remains unimplemented largely due to concerns of the enforcement office. They told us that they held discussions with enforcement officials last year to try to address their concerns. However, they stated that since the two offices have not been able to reach a consensus on how to implement the program, EPA's Office of Water has postponed taking further actions.

Conclusions

Technologies exist that can monitor many of the pollutants of interest found in wastewater discharges from sewage treatment plants and industrial facilities. While incremental improvements to these technologies continue to be made, more significant advances have been less frequent. EPA's lengthy approval process has dissuaded instrument manufacturers from pursuing major innovations. Because instrument manufacturers are reluctant to pursue major modifications or the development of new methods, regulated entities may be missing opportunities to use significantly improved technologies that can improve the accuracy of monitoring or lower its cost.

EPA has taken steps to mitigate this problem by improving its approval processes. The agency successfully streamlined its approval of methods that are minor modifications to existing ones. However, in fiscal year 2001, the agency eliminated the $75,000 in contractor funding that had supported its process improvements. Such reductions threaten to reverse the gains that have been achieved.

The approval of major modifications or new methods is particularly problematic. The proposed use of a performance-based measurement system by EPA's Office of Water offers a promising alternative to the review and rulemaking process, although there are implementation issues that still must be resolved. If EPA wants to promote and embrace innovative use of wastewater monitoring technology, the agency needs to resolve these issues before implementing such a system.

Recommendations

To ensure that the applications for minor modifications or limited use methods continue to receive timely review, we recommend that the Administrator, EPA, direct the Office of Water to track the results of its review and approval of these applications over the course of the coming year. The Office should compare these results to those of recent years to determine the impact of fiscal year 2001 funding reductions on the timeliness of its reviews. If the agency determines that funding reductions have had a significantly negative impact, it should consider restoring the funding or taking other measures to compensate for the loss of such funding.

To encourage the development of new or significantly improved test methods for use in wastewater monitoring, we recommend that the Administrator, EPA, direct the Office of Water and the Office of Enforcement and Compliance Assurance to work together to resolve remaining differences over the use of a performance-based measurement system in wastewater monitoring, and to move forward with implementation of the agreed-upon system.

Agency Comments

EPA's Offices of Water and of Enforcement and Compliance Assurance did not provide comments on the material covered in this chapter. The agency's Office of Research and Development provided several comments, which largely involved technical suggestions and clarifications. For example, one official suggested we clarify that while technologies have been developed to measure most classes of pollutants in wastewater, practical detection techniques do not yet exist for some important *individual* pollutants. We made revisions in response to this and other comments as appropriate.

Chapter 4: Technologies for Measuring Emissions From Nonpoint Water Sources

Measuring pollutant discharges from nonpoint sources is very different than measuring discharges from wastewater sources or emissions from stationary air sources. Because of the diffused nature of nonpoint sources, direct monitoring of pollutant contributions is exceedingly difficult and resource intensive. Consequently, the measurement of nonpoint discharges typically involves an analysis of various sources of data, such as those on water quality conditions and land use practices, to estimate potential pollutant contributions. We identified numerous technologies that can aid in these estimates by obtaining more detailed data and increasing analytical capability.

While most nonpoint source assessments are conducted by states, research-oriented organizations, such as universities and the U.S. Geological Survey (USGS), are more likely to use advanced technologies in water quality investigations. Lack of funding, expertise, and time limit the more widespread use of advanced technologies and techniques. In addition, there is no central repository for information on the development and application of new technologies and techniques useful in nonpoint source monitoring and assessment. As a result, users may be missing opportunities to capitalize on lessons learned and to avoid duplication of effort.

Monitoring and Assessing Nonpoint Sources of Water Pollution

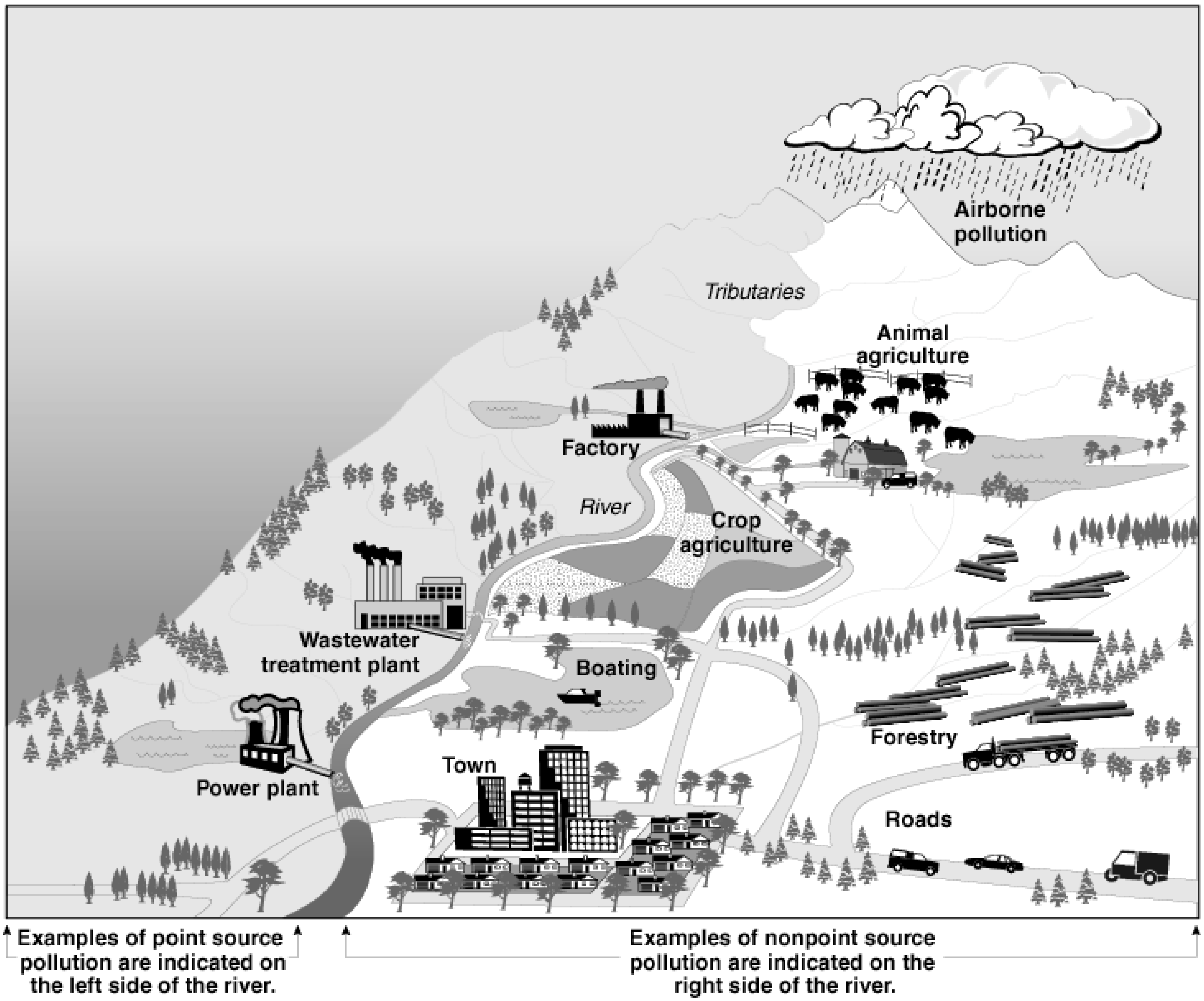
The diffused nature of nonpoint sources makes the direct measurement of their individual pollutant discharges exceedingly difficult. However, the importance of assessing pollutant contributions from nonpoint sources has increased rapidly in recent years, given the intense pressure on the states and EPA to develop pollutant reduction strategies for waters that do not meet water quality standards. (These pollutant reduction strategies are called "Total Maximum Daily Loads," or TMDLs.) While there is no estimate for the number of nonpoint sources affecting these waters given their numerous and diffused nature, states reported in 1998 that almost 300,000 miles of rivers and streams and about 8 million acres of lakes were not meeting water quality standards; nonpoint sources are cited as contributors to most of these polluted waters.[1]

In a watershed with multiple sources of water pollution, it is often difficult to determine the amount of a pollutant any given source has contributed. For example, agriculture, pet waste, and homeowner lawn

[1] These figures apply only to the minority of U.S. waters that have been assessed. For example, 840,000 of the 3.6 million total miles of streams have been assessed.

maintenance can all contribute nutrients (nitrogen and phosphorus) to nearby waters, but most monitoring reveals only the level of nutrients present and cannot identify the sources that contributed the nutrients or the amounts they contributed. As a result, measuring nonpoint source pollution often requires an analysis not only of water quality conditions, but also of (1) the activities occurring on the land that could be potential contributors of pollution and (2) the factors that influence the transport of pollution to waters. Figure 5 illustrates the diffuse nature of nonpoint sources of pollution as compared to point sources.

Figure 5: Nonpoint and Point Source Water Pollution



The assessment of pollutant contributions from nonpoint sources relies on many data types. In addition to monitoring data on water quality conditions, information on land use/land cover (the vegetation or suburban/urban development present), soil type, climate, and topography all help to identify potential pollutant sources and to explain pollutant transport dynamics (how quickly pollutants travel from their source to receiving waters). Given the complex relationships among these various factors, mathematical models are often used to translate these data into probable pollutant contributions from individual sources or groups of similar types of sources.

The Clean Water Act directs states to develop programs that address nonpoint source pollution but it provides no direction for the establishment of minimum national controls or monitoring that must be implemented, such as it does for the control of wastewater dischargers. As a result, there is no formal approval process for identifying acceptable monitoring methods or techniques, such as the approval processes used in the stationary air or wastewater programs. While states bear the responsibility under the Clean Water Act for dealing with nonpoint source pollution, numerous federal, state, local, and other organizations monitor water quality conditions and generate other types of data used in nonpoint source analyses.

Available Technologies That Can Improve Monitoring and Assessment

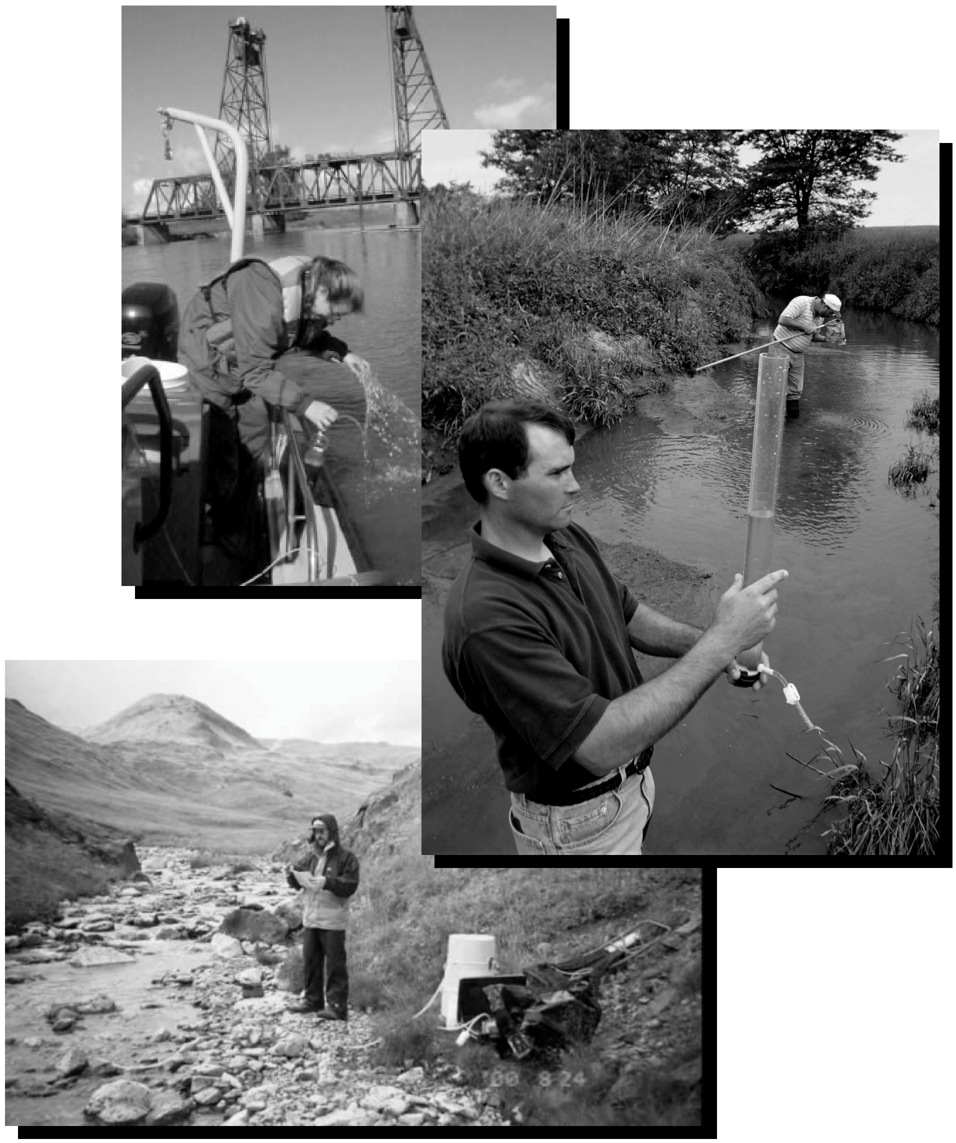
Pollutant contributions from nonpoint sources are diffused, numerous, and difficult to quantify. Traditional water quality monitoring techniques, such as in-person sampling, are too resource intensive to monitor all the areas needed. In addition, the availability of an increasing amount of related (or ancillary) data requires the use of analytical tools to process them. There are several areas where improved technologies can assist in (1) the sampling and analysis of water quality and (2) the integration and analysis of multiple sources of related information.

Water Quality Sampling and Analysis

There are several improved technologies or methods for taking and analyzing a water sample. While advances in laboratory-based measurements, such as those discussed in chapter 3, will benefit nonpoint source analysis, the users that we interviewed said that, in general, the greatest benefits come from field-based monitoring and analysis devices.

Sampling Methods: Much of the data on water quality conditions that are needed to assess nonpoint source pollution is collected manually—a person physically collects water samples from a body of water. Such a process is costly and time-consuming because staff must travel to the location, follow certain protocols for collecting samples, and transport the samples to a laboratory for analysis. In-person sampling can also sometimes be hazardous because most nonpoint source pollution occurs during high flow events, such as storms. Figure 6 shows several in-person sampling methods. In certain situations, however, automatic sampling devices can be used. These devices, which are triggered remotely by a user or by the high flow event itself, collect water samples and store them for later transport to a laboratory. While a person must still travel to the sampling location, the device can take numerous samples over a period of many days or weeks. This type of “remote sampling” provides significant improvements over manual collection in terms of the number of areas that can be sampled during a high flow event, the frequency of sampling, and safety.

Figure 6: Examples of In-person Water Sampling Methods



Source: U.S. Department of Agriculture and U.S. Geological Survey

Field-based Analytical Methods: Some monitoring technologies allow users to measure various water quality parameters in the field. Obtaining pollutant measurements in the field is helpful in (1) reducing monitoring costs by eliminating certain laboratory analysis, (2) providing real-time results, and (3) enabling more efficient monitoring by facilitating decisions about data adequacy and determining whether additional measurements need to be taken—such a course of action is impossible when waiting for a result from a lab analysis. Field-based technologies either provide results instantaneously for manual recording, store results on disk within the instrument for later downloading, or communicate results remotely via telemetry, cellular phone, or satellite communications. In addition, some of the field-based technologies can be left alone to analyze pollutant levels continuously or at set intervals. This is particularly beneficial in measuring pollutants like dissolved oxygen or nutrients, the concentrations of which may vary throughout the day depending on temperature changes or flow levels. Field-based "sensors" are considered reliable for several common water quality measurements of interest, such as temperature, dissolved oxygen, and conductivity. Field-based "analyzers" are generally more sensitive than sensors and measure pollutants that are more complicated to quantify, such as nitrates, although their reliability at low levels is not yet well defined.[2]

Pathogen Source Detection: Methods exist that use DNA analysis to identify the source species of fecal-related bacteria in water. For example, a project in Arizona used this technique to determine what percentage of fecal coliform came from human, pet, and wildlife sources in a stream used heavily for recreation. Preliminary results of the analysis indicated that the initial perceptions about the source that contributed the most bacteria were not correct. Similarly, studies in Virginia and Washington revealed surprising findings that animals were the primary source of fecal-related bacteria in certain waters, not leaking sewers or septic systems as researchers had originally suspected. Identifying sources of pollution in cases like these is critically important to devising effective pollution reduction strategies when the largest sources may not be obvious or easily controlled.

Information Integration and Analysis

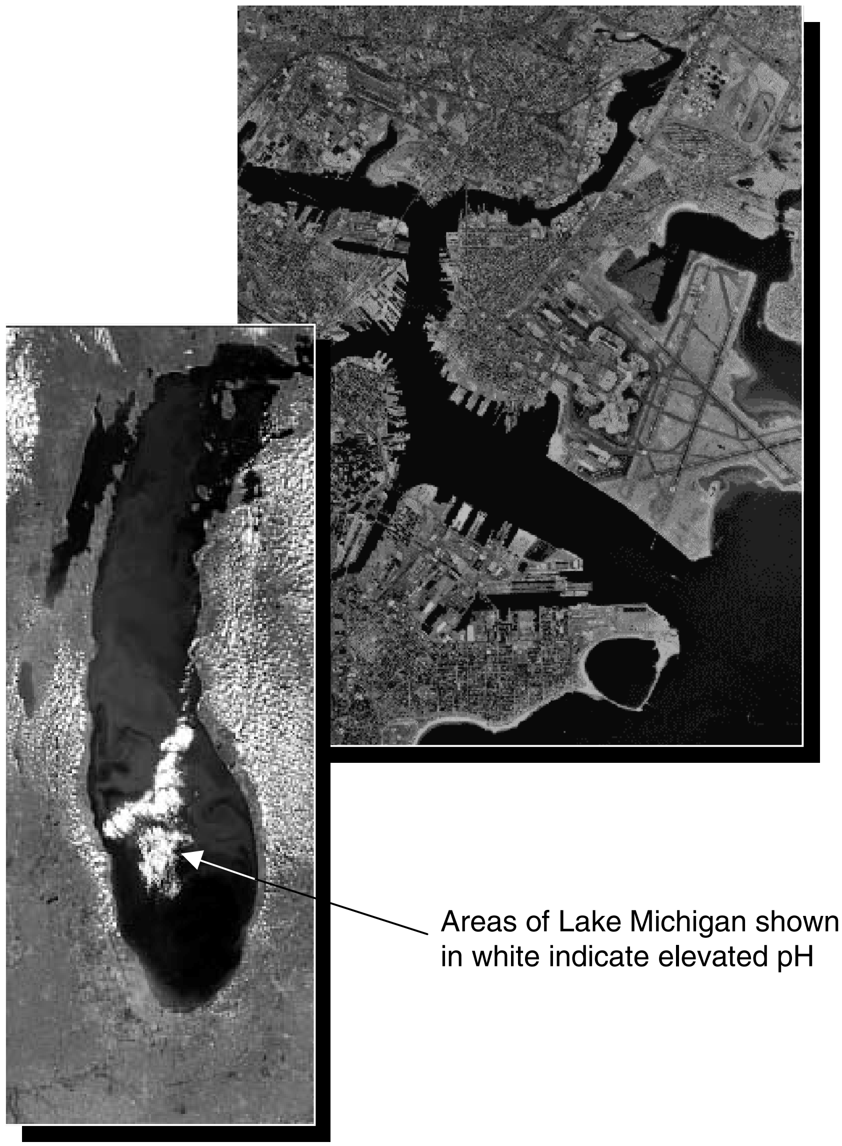
While there are advances in taking water samples and conducting analyses or measurements of pollutants, most of the individuals that we interviewed also recognized the improvements in integrating and analyzing multiple types of data as essential elements in nonpoint source assessment. Understanding pollutant dynamics requires information about

[2] Analyzers can take more precise measurements than sensors but can also be significantly more expensive and difficult to maintain.

a multitude of diverse but interrelated elements, such as hydrology, soil type, climate, and land use/land cover. Obtaining information in all these areas is resource-intensive and challenging. Without computers and other analytical tools to assist in the management of this information, the organization and interpretation of these disparate data would be resource prohibitive.

Remote Sensing: Remote sensing technologies, such as satellite imagery and aerial photography, observe characteristics without coming into direct contact with them. Thus, remote sensing can provide the capability to gather data about remote, hazardous, or inaccessible areas. Photographs and images can be used to identify possible sources of pollution and can be taken over time to track land use changes that may influence water quality, such as rapid urbanization. Remotely-sensed data can also be used to feed mathematical models or geographic information systems that aid in nonpoint source assessments, such as in ranking watershed areas with the highest potential for runoff. The interpretation of satellite imagery and aerial photographs, however, is required to connect them to water quality matters; this process requires specialized skills. In addition, some fieldwork may be needed to verify the accuracy of image interpretation. Figure 7 provides examples of remote sensing.

Figure 7: Examples of Remote Sensing



Source: The National Aeronautics and Space Administration (Lake Michigan photo) and the U.S. Geological Survey (Boston Harbor photo).

Models: Computerized models and similar analytical tools can assist nonpoint source assessment by automating the analysis of the complex relationships that define how pollutants move through the environment—

analysis that would be extremely difficult and time-consuming to do manually. Models can also simulate the potential effect of various control actions on pollutant transport. Models have been used in hydrologic applications for decades, although historically they have been largely focused on (1) discrete pollutant transport (such as that used in analyzing pollution impacts from wastewater sources) or (2) individual components of watershed functioning, such as groundwater movement or urban stormwater runoff. Recently, EPA has focused on expanding the use and capability of models in order to meet the demands of assessing nonpoint sources and developing TMDLs. Many of the improvements made in this area have focused on making models "simple." This simplification has been accomplished by making the front or back end processing—the user interfaces for data input and output—more user-friendly; for the most part, improvements have not focused on modifying the model itself. Therefore, some of the underlying models may still be complex, but the interface with which a user interacts has been simplified.

Geographic Information Systems: Geographic information systems (GIS) manage data according to their spatial or geographic location. GIS can incorporate remote sensing information (such as land use information, which is often generated via satellite imagery) and aid in modeling. For example, the models may be simplified by providing (1) a GIS-based user interface to assist in data entry and (2) the capability of generating easy-to-read maps to present model results. GIS software is available in varying levels of sophistication and computer resource capabilities. For example, basic analytical and geographic capabilities can be performed on an average stand-alone personal computer. GIS provides a powerful tool for integrating large amounts of data that could otherwise be prohibitively expensive. As such, these systems have revolutionized how water quality data can be related to land use and have provided exponential improvements over prior manual methods that were used to process and interpret information. One official we interviewed said that GIS is the "glue" that holds the data together for assessments of nonpoint source pollution. Another noted that GIS has "endless" opportunities for analyzing data.

Extent to Which Improved Nonpoint Source Monitoring Technologies and Assessment Techniques Are Being Used

It is difficult to determine the extent to which a particular nonpoint source-related technology is being used. The different entities that conduct nonpoint assessments may use whatever technology they choose and there is a multitude of these assessments taking place across the country. However, based on our discussions with a diverse group of individuals involved in nonpoint source monitoring and assessment, it appears that the overall use of advanced technologies is limited. Less expensive technologies or those that require less time and specialized skills to use are more often used than their more expensive and complex to use counterparts. In addition, the organizations that are most likely to use advanced technologies focus on research or in-depth water quality investigations rather than on regulatory requirements of the Clean Water Act. Many officials that we interviewed told us that there is a pressing need for better information sharing about the successes and failures of technologies and techniques used in nonpoint source assessments.

Most Used Advanced Technologies and Techniques are the Most Affordable and Easiest to Use

Several officials we interviewed told us that the increased attention on nonpoint sources, spurred by numerous TMDL lawsuits, has provided states a strong incentive to use monitoring technologies and methods that increase the amount and reliability of water quality information. Two state officials told us that they expected that the public and pollutant dischargers will impose increased scrutiny on states' assessments of nonpoint source pollution for development of TMDLs, and legal challenges may be levied against some TMDLs. According to many officials we interviewed, the use of advanced technologies or techniques will hopefully yield a better understanding of water quality problems and more informed decisions regarding the needed pollution controls.

Yet, however strong the benefits may be, most states have only capitalized on a few advanced technologies. According to state officials that we interviewed, most use automatic samplers and field-based analyzers for at least some of their monitoring and assessment activities. They noted that while they can afford to purchase at least some of these instruments and already have expertise to operate and maintain them, they cannot afford to buy enough of these instruments to use in the majority of their monitoring activities. In addition, some officials we interviewed said that users are sometimes reluctant to experiment with untested or unproven technologies.

States also use "simple" models—those that have improved user interfaces and graphic output—when conducting nonpoint source and TMDL analysis. An EPA official told us that states increasingly use these models in cases where they must develop TMDLs quickly and where little site-specific data exist. These simple models are easily accessible because most of them are in the public domain, and given the advancements in user interfaces, they are now easier to use than they were in the past. However, the same advances that have increased the use of these models also make it easier to misuse them. Some officials told us that users may not fully understand the underlying model or know whether they are using the model appropriately. In addition, an essential component to model usage is calibration and validation—processes that must be done using site-specific data. Unreliable and misleading results can be generated if a model is not properly calibrated and validated. However, as noted above, these models are increasingly being used in cases were little site-specific data exist. Several individuals we interviewed expressed great concern over the use of models in these cases and expected to see challenges to resulting TMDLs. These concerns were echoed at a recent conference focused on the science needed to support TMDL development.

While states have limited abilities to use advanced technologies, we found that research-oriented organizations use advanced technologies and techniques more frequently in their monitoring and assessment activities. Research organizations, such as USGS and universities, use automatic samplers, field-based analyzers, and simple models in their water quality investigations and devote resources specifically to develop and experiment with new technologies and techniques. Consequently, they are able to develop and maintain the specialized expertise needed to use many advanced technologies.[3]

Complex, Expensive Technologies and Techniques Are Used to a Very Limited Degree

The disparity between the abilities of states and research organizations to obtain and use advanced technologies and techniques becomes much greater with the more advanced technologies, such as GIS, remote sensing, and complex models. In general, only research-oriented organizations and a few high profile special projects use the most advanced technologies; states rarely use them for routine assessments.

States' use of GIS, remote sensing, and complex models in their nonpoint source and TMDL analyses is very limited. Equipment purchases and

[3] USGS also cautions that the range of water quality issues these tools can address is limited. It notes, for example, that the tools do not apply well to bacteria and not at all to bacteria source tracking.

training to use the advanced technologies require a significant commitment of resources. However, water quality monitoring is often found on the bottom rung of the funding ladder within state programs. Many officials we interviewed cited the cost of purchasing advanced technologies and the time needed to acquire the skills to operate and maintain them as major barriers.

Organizations that conduct research or high profile water quality projects, however, use GIS, remote sensing, and complex models more frequently. For example, USGS uses these tools to collect, integrate, and analyze water quality and related data in its water quality investigations. The agency notes that the use of these techniques, even in limited situations, can provide very important insights and information. Similarly, the Chesapeake Bay Program (an interagency program led by EPA) uses these tools to analyze pollutant dynamics within the Chesapeake Bay ecosystem. High profile state projects may also use GIS, remote sensing, and complex models. For example, North Carolina has been using complex models to study nutrients in the Neuse River—one of the state's priority water quality projects. These organizations and projects are focused on obtaining a detailed understanding of complex water quality problems that may require experimenting with advanced technologies.

However, research organizations or special projects do not always routinely use advanced technologies. For example, an analyzer exists to measure nutrients at low levels and has the potential to provide critical needed data for the thousands of waters impaired by nutrients, yet its reliability has not been accepted. Therefore, it is currently being tested at a handful of universities and USGS. Even if the analyzer proves to be reliable, however, it is unlikely that it will be used widely because it costs about $20,000 and the skills of a trained chemist are needed to operate it and understand its results. One USGS official testing the analyzer said that he did not envision its widespread use across the agency because of its cost and the level of specialized skill required to interpret the results. Similarly, DNA source identification is very expensive and used in only a limited number of projects.

Lack of Information Sharing Misses Opportunities for Improved Efficiency

Many officials that we interviewed recognized the need to improve information sharing regarding technologies and techniques used in nonpoint source assessments and TMDL development. Information sharing is particularly important in an area as decentralized as nonpoint source pollution, for which assessments tend to be more of an interpretative exercise—often relying on best professional judgment—

rather than a simple monitoring exercise. While advanced technologies provide many improvements to users, how these technologies are applied in specific circumstances is often just as important. One official told us that he believed that he had duplicated the work of others in his efforts to modify a streamflow sensor to a particular application. Information sharing is therefore all the more important in allowing users to capitalize on lessons learned elsewhere, avoid duplication, and move forward with their analyses more quickly.

EPA has facilitated some information sharing regarding nonpoint source monitoring and assessment. For example, EPA holds an annual conference to share lessons learned from its national nonpoint source monitoring program—a program that focuses on long-term, intensive monitoring in about 20 waters around the country. The program is intended to evaluate the effectiveness of nonpoint source pollution controls and improve the understanding of nonpoint source pollution. In addition, EPA maintains a periodic newsletter on many aspects related to nonpoint source pollution on the agency's webpage. However, as one user pointed out, there is no central clearinghouse for information about new technologies for use in nonpoint source assessments. Such a clearinghouse could help connect users who share common experiences and reduce potentially duplicative efforts.[4]

[4] In commenting on a draft of this report, the Department of the Interior noted that the interagency National Water Quality Monitoring Council has taken some steps toward information sharing through development of a National Environmental Monitoring Index. The index is intended to provide a comparison of water quality monitoring methods and includes information such as the instrumentation employed, sample preservation and storage requirements, and relative cost. However, information sharing is also needed regarding analytical approaches and techniques useful in assessments of nonpoint source pollution. The Department notes that the index could be expanded to include other technologies and techniques mentioned in this report, such as GIS and mathematical models.

Factors That Influence Development of Improved Nonpoint Source Monitoring Technologies and Assessment Techniques

Because many different types of technologies and techniques exist to aid nonpoint source assessments, the development of improvements to them may follow one of several different paths. The private sector conducts some development, such as the case of the automated devices used to sample and analyze water quality. Other development is primarily federally conducted or sponsored, such as the case of many of the models in use today. In addition, users often make refinements, enhancements, and other modifications to technologies and techniques as more is learned in site-specific projects.

Several factors make the development of nonpoint source monitoring technologies or assessment techniques particularly challenging. The first is the lack of specific monitoring requirements for this type of pollution. In the past, explicit monitoring requirements for air and wastewater sources led to a predictable and guaranteed market for individual monitoring technologies. While states are required to monitor their waters and to assess water quality, there are no specific requirements for how that monitoring should occur and what technologies or methods should be followed. Hence, as the instrument manufacturers we interviewed pointed out, there is no clearly defined market for nonpoint source monitoring technologies and assessment techniques.

A second challenging factor is the size of the potential market for nonpoint source monitoring technologies and assessment techniques. Water quality monitoring and assessment have historically received less funding than other water and environmental programs. As such, instrument manufacturers we interviewed acknowledged that the market for their products was fairly small. For example, an official from a GIS developer said that developments in GIS technology have largely been geared toward well-funded applications, such as transportation planning and facilities management, and not for natural resources management. In addition, the president of one manufacturing company, who was modifying a defense-related sensor to the water quality market, told us that the return on investment takes longer in the environmental market than for other technology markets. He said that unlike other technology areas where users are quick to purchase new technologies, the environmental market is generally not very responsive to new technologies, partially due to resource constraints.

Modeling—an area in which much of the past development has been federally conducted or sponsored—similarly suffers from a lack of investment. While most needs are being met through existing models, some users told us that solving very complex nonpoint source pollution problems requires more advanced tools than exist today. In addition, some users noted that the basic models have received no major modifications in several decades. However, progress on improving the models themselves is limited mainly because EPA—the agency that has traditionally conducted or funded a large portion of water quality model development in the past—has cut funding in this area by about 75 percent since the mid-1990s. According to an official from an EPA laboratory primarily responsible for this work, the agency plans to pursue improvements to existing models and work on new models, but progress will be slow given the limited funding devoted to this area.

The lack of information sharing—discussed earlier as a problem impeding wider use of advanced technologies—is a third problem that constrains development of new or improved technologies and techniques. As noted previously, users are sometimes reluctant to experiment with new and potentially unproven technologies. However, until users do so and document their experiences, it is not clear what additional development is needed or where it could be of most value. For example, according to several of the users that we interviewed, information on the effectiveness of various best management practices needs to be improved. While some users thought that additional research was needed to determine the effectiveness of such practices, others thought that inventorying the work already done would yield most of the information needed. However, until an inventory is done, it is not clear what needs for technology and tool development remain.

Conclusions

Recent emphasis on addressing polluted waters has placed increased importance on identifying nonpoint source pollutant discharges quickly, accurately and at lower costs. However, the absence of explicit nonpoint source pollution monitoring requirements, combined with the historically low level of funding being devoted to nonpoint source monitoring, has discouraged wider investment in this area.

We found these challenges to be further compounded by a scarcity of information concerning the numerous data, technologies, and analytical tools that are used in the multitude of nonpoint source assessments that are being conducted each year. The scarcity of such information makes it difficult to identify which tools are most useful under specific circumstances. This additional complication, however, could be substantially alleviated if a centrally situated organization—such as EPA—routinely catalogued and publicized information about which monitoring technologies and assessment techniques work, and why they work. We believe that doing so could go a long way in (1) maximizing the relatively small investment currently being made in monitoring and assessing nonpoint sources, (2) providing greater assurance that resulting recommendations for pollutant controls are cost-effective and successful, and (3) guiding the efforts of those attempting to identify the most promising new technologies and other tools for investment.

Recommendations

To improve the sharing of information and reduce duplication, we recommend that the Administrator, EPA, direct the Office of Water to develop a clearinghouse and/or locator for monitoring technologies and assessment techniques that are used for assessing pollutant contributions from nonpoint sources and developing TMDLs. Such a clearinghouse should include (1) a mechanism whereby users could obtain and update information regularly and easily and (2) information provided by EPA and the other federal agencies that collect and analyze water quality conditions.

Agency Comments

EPA did not comment on the material in this chapter. The Department of the Interior said that it agreed with our recommendation that EPA develop a clearinghouse and/or locator for monitoring technologies and assessment techniques that are used for assessing pollutant contributions from nonpoint water pollution sources and for developing Total Maximum Daily Loads. It suggested, however, that the report note that the interagency National Water Quality Monitoring Council has already made some progress in this direction through the establishment of a National Environmental Monitoring Index. We added language to this effect in this chapter, and incorporated several other technical comments and clarifications suggested by the agency. The text of Interior's letter is included in appendix. I.

Appendix I: Comments From the Department of the Interior

United States Department of the Interior

OFFICE OF THE SECRETARY
Washington, D.C. 20240

JUN 12 2001

Mr. John B. Stephenson
Director, Natural Resources and
Environment
United States General Accounting Office
Washington, D.C. 20548

Dear Mr. Stephenson:

Secretary Norton provided me a copy of your draft report entitled "Environmental Protection: Wider Use of Advanced Technologies Can Improve Emissions Monitoring," (GAO-01-313) to review. As you know, staff of the U.S. Geological Survey (USGS) was contacted by your office to provide information.

While there are no recommendations for the USGS, USGS staff has provided the following comments:

> The comments address the nonpoint contamination monitoring subject, as neither the USGS nor the Department of the Interior have responsibility for monitoring stationary air sources or point sources of wastewater discharge.
>
> USGS has one comment on the recommendation for nonpoint source monitoring and then several specific comments by page number. The recommendation to have the Administrator of the Environment Protection Agency (EPA) develop a clearinghouse and/or locator for monitoring technologies and assessment techniques is a logical conclusion. The General Accounting Office (GAO) may want to recognize that EPA and other agencies are already doing some of that type effort through the National Water Quality Monitoring Council in developing a National Environmental Monitoring Index (NEMI). The NEMI effort is starting with analytical laboratory methods, but will also eventually include field sample collection methods and perhaps some other monitoring approaches. The GAO recommendation is appropriate and goes beyond both the current status of NEMI and perhaps the overall goal of NEMI too. The GAO may want to acknowledge the work that is already ongoing and suggest the extension of those efforts to include other aspects mentioned in the report such as: automatic samplers, field analyzers, remotely sensed data, Geographic Information System (GIS) coverage, and models. Also, GAO has suggested identifying what works and what does not work which may also extend beyond NEMI objectives and goals. For further discussion, GAO may

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want to talk with Herb Brass of EPA in Cincinnati (513) 569-7936 or brass.herb@epa.gov).

Now on p. 52.

p. 48—"... states reported in 1998 that almost 300,000 miles of rivers and streams and about 8 million acres of lakes were not meeting water quality standards; ... " The GAO might want to mention that these numbers are only for the rivers and streams reported on 23 percent of the total in the Nation, and 42 percent of lake acres in the Nation. Thus the 300,000 stream miles impaired are out of the 840,000 miles assessed, but there are over 3.6 million miles of streams and rivers in the United States.

Now on p. 52.

p. 48—"For example, wastewater treatment plant, agriculture, pet waste, and homeowner lawn maintenance ... " While all of these do contribute to nutrients reaching streams, all are nonpoint sources except for wastewater treatment plants, which are regulated point sources discussed in the previous chapter and should be monitored as part of the permit requirements.

Now on p. 53.

p. 49—"... but also of (1) the activities occurring on the land that could be potential contributors of pollution and (2) the factors that influence the transport of pollution to waters." The GAO could mention here that with these additional sources of data, one can begin to associate activities and factors with contaminant concentrations or contaminant loads.

Now on p. 55.

p. 50—"Sampling Methods" Two limitations of automatic samplers could be mentioned. (1) Automatic samplers can only be used for certain constituents because of (a) preservation issues and (b) sampling protocols (for example, sterile sampler for bacteria). (2) The sample collected by an automatic sampler is a point measure; this point sample must be calibrated to the cross-sectional mean measure through the manual collection of samples. The second point is important for any contaminants associated with sediment particles (metals, some pesticides) because they are not evenly distributed in the stream cross-section and the automatic sampler may produce biased (either high or low) results leading to erroneous conclusions.

Now on p. 59.

p. 52—"The interpretation of satellite imagery and aerial photographs, however, requires specialized skills." It is known as well that the interpretation aspect of these images is both required for connections to water-quality data and issues, and the interpretation is the most expensive aspect of acquiring the image data in a useable form.

Now on p. 61.

p. 52—"Geographic Information Systems" Effective use of GIS requires a substantial and continuing investment in computer hardware and software. Capabilities in the GIS field and improvements in the hardware and software happen quickly enough that continual investment is needed to keep a viable GIS activity going.

Now on p. 62.

p. 53—"According to state officials that we interviewed, most use automatic samplers and field-based analyzers for at least some of their monitoring and assessment activities." Those techniques, however, do not apply well to issues on contaminants like bacteria and not at all on issues like bacteria source tracking. Thus, there is a limited range of water-quality issues (as opposed to a comprehensive range) that automatic samplers and field analyzers can currently address.

Now on p. 63.

p. 54—"Complex, Expensive Technologies and Techniques Are Used to a Very Limited Degree" It is true that complex and expensive techniques are used to a limited extent. This is true in other sciences--there are only a few proton accelerators at use in the nation. However, it is worth noting again that even the limited use of these techniques can provide very important insights, understanding and information (this was alluded to on p. 51 under "Pathogen Source Detection").

Now on p. 66.

p. 56—"Factors That Influence Development . . . " There is a brief mention of transferring a defense-related sensor (no doubt developed with public funds) to the environmental market (private sector). It seems, based on what USGS knows from Sandia Labs and vendors, that there is tremendous opportunity to utilize defense-related sensors and samplers for environmental applications. The Federal Government can take a lead role in ensuring that the public investment in the defense-related sensors is fully utilized for natural resource management and protection, which is also a Federal role. If even a percent or two of the funds used to develop these sensors was available to "research organizations" for technology transfer and testing, that could help make great strides in both information and understanding. (Note that these "sensors" can be both *in situ* and remote.)

Thank you for the opportunity to review and to comment on the draft report before it is finalized.

Sincerely,

Amy Holley

Amy Holley
Acting Chief of Staff
Office of the Assistant Secretary for
Water and Science

Appendix II: GAO Contact and Staff Acknowledgments

GAO Contact

Steven Elstein, Assistant Director, (202) 512-6515

Acknowledgments

In addition to the individual named above, Michael Hix, Jason Holliday, and Patricia McClure made key contributions to this report. Important contributions were also made by Chuck Bausell, Tim Guinane, Karen Keegan, and Jonathan McMurray.

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