Monitoring, Assessment, and Environmental Policy[*,†]

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The uses of monitoring and assessment in environmental policy-making

Perhaps the earliest example of environmental monitoring, assessment, and policy-making was John Snow's careful collection of data on the incidence of cholera in 19th Century London (monitoring). Analysis of the data led him to identify a contaminated well on Broad Street as the most likely source of infection (assessment). The authorities subsequently closed the well by removing the pump handle (policy-making).[1] We have come a long way since then. The other chapters in this volume describe advances in monitoring technology and the implementation of major monitoring networks. Assessment has become increasingly complex and formalized. Policy-making has moved well beyond decisions by local authorities and is now national, multinational, and international in scope. In this overview, we examine some examples of the roles that monitoring has played in assessment and environmental policy since Snow's earlier, simpler time.

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Monitoring, in the context of this chapter, is the systematic collection of data for the purpose of checking on the environment, as opposed to collection of field data primarily to support a scientific study. *Assessment* is the process of analyzing and evaluating the resulting monitoring data, together with other scientific evidence, to support policy-making. Although science and assessment are inextricably linked, science is the discovery of knowledge through research, whereas *assessment* involves analyzing the quality of scientific understanding and bounding the uncertainties, so that decision-makers can act with an appropriate interpretation of the benefits, costs, and risks of alternative policies.[2] *Policy* is any course of action intended to guide decisions about whether and how to protect or restore the environment. Examples include treaties, legislation, executive orders, administrative rulemaking, execution of regulations, and even stimulation of private sector actions by government. Policy-making may occur *within* a given decision-making structure, or it may involve deliberations about the decision-making structure itself.[3]

Environmental policy-making can involve:

1. Identifying and analyzing environmental problems
2. Formulating policy and setting goals and priorities
3. Executing policy and managing programs
4. Evaluating policy and program performance

Monitoring and assessment can contribute to policy-making through one or more of these activities. This overview will examine some of the significant national and international environmental policy issues of the past four decades, to try to determine whether monitoring data either did or didn't play a *key* role in each of the four policy-making activities. The international issues include acid precipitation, stratospheric ozone depletion, and global climate change; the national issues include criteria air pollutants and water quality management in the U.S.A. We will conclude with a look at the use of monitoring and assessment to support environmental “report cards” as potential policy tools.

While it is tempting to try to make a case for the relative importance of monitoring versus other sciences (e.g., modeling or toxicology) in any particular policy decision, the various science underpinnings are usually too inextricably linked to support such a conclusion. Consequently, when we conclude that monitoring played *a* key role, that is not to say that it played *the* key role. Even more important, in the words of the late Congressman George E. Brown, a long-time participant in environmental policy-making in the U.S. House of Representatives, “Political expediency will always play a greater role in policy-making than will analytical thinking, scientific or otherwise.”[4] Congressman Brown’s remarks remind us that the role that monitoring plays in policy-making may never be known precisely, and perhaps least of all by scientists seeking objective truth based on falsifiable data.

In order to keep this overview to a manageable length, we have limited its scope. The choice of examples is influenced by the author’s experience with air and water policy in the U.S.A., and under-represents national examples from other countries and other environmental policy areas (e.g., natural resource management). Monitoring of pollutant emissions and of enforcement actions are not considered, even though they can and have played important roles in policy-making. Discussions of the examples rely heavily on overview papers which provide a wealth of information on other factors that influenced the corresponding policy decisions, and they should be consulted for primary literature sources not explicitly referenced in the text.

Acid Precipitation

The early history of the acid precipitation problem is described by Likens[5] and Cowling,[6] and the more recent history by Clark et al.[7] and Sundqvist et al.[8] Acid precipitation was identified as a potential problem in 19th Century England by Smith, and its harmful effects were explored in the 1950s by Gorham. However, identification of acid precipitation as a major issue by the public did not become widespread until newspapers in Sweden began extensive coverage of an analysis of monitoring data by Oden in the late 1960s. Monitoring data from a network put into place in western Europe in the early 1950s showed that acid precipitation had increased substantially in both intensity and geographic extent, and that the increases could be correlated with monitoring data on emissions from stationary sources, some of which were hundreds of miles distant. This public attention led the Swedish government to present a case study at the 1972 U.N. Stockholm Conference on the Human Environment, that led to the establishment of major government research programs in Europe and North America to more thoroughly analyze the problem.

In the U.S., monitoring at an experimental watershed at Hubbard Brook in New York and at a few stations run by individual investigators around the country demonstrated that acid precipitation was already a widespread phenomenon in eastern North America in 1976, and that changes in the ratios of sulfuric and nitric acids could be correlated with monitoring data from emissions sources. Monitoring of lakes and streams in the U.S and Canada also showed large numbers of acidified surface waters and declines in certain fish species. The National Acid Deposition Network (NADP) was established in the late 1970's (Chap by Kutz/Bradley) to collect data nationwide. In 1979 international agreements were in put in place between the U.S., Canada, and the European Community to analyze these problem and to seek potential solutions, and in 1980 Congress established what was to become the decade-long, $530 million National Acid Precipitation Program (NAPAP). NAPAP culminated in an Integrated Assessment in 1991 that analyzed the impact of alternative emissions reduction targets on the future acidity of surface waters in the Eastern U.S., and the costs of the various alternatives.[6] The results of the NAPAP integrated assessment, which relied heavily on data on emissions, patterns of the acidity in precipitation from the NADP network, and statistically reliable patterns of the chemistry of lakes, streams, and soils established by systematic data collection by the National Surface Water Survey, showed that a 50% sulfate emissions reduction would significantly reduce the acidity of lakes and streams in sensitive parts of the U.S. and Canada.[9] Although there was concern about the potential effects of acid rain on forests in Europe and the U.S., much of the data were based on experimental studies, and even when surveys demonstrated higher than expected mortality of spruce-fir and sugar maple, there were enough confounding factors that the NAPAP Integrated Assessment did not conclude that there was clear monitoring evidence linking the declines to acid deposition.

It is certainly clear that analysis of monitoring data on both precipitation and surface waters played a key role in *identifying the acid precipitation problem* and bringing it to international attention. There has been much debate, however, about the extent to which the analysis of data in NAPAP (and NADP) ultimately played in *formulating policy and setting goals and priorities* in the acid rain provisions of the Clean Air Act Amendments (CAAA) of 1990.[10] The ultimate reduction target of 50% of sulfate emissions supported by the NAPAP assessment was exactly what was envisioned in a 1981 National Academy of Sciences Report that had set the stage for the acid rain policy debate in the U.S.[11]

Environmental monitoring appears to have played a modest role in *executing and managing* acid precipitation programs in the U.S. and Europe, even though the approaches are very different. In the U.S., the CAAA adopted a cap-and-trade approach that set a cap on sulfur emissions from certain categories of sources nationwide, and allowed sources to trade emissions credits to insure that the cap would be attained by reducing emissions at the facilities where the reductions were the most economical, irrespective of the effects on downwind ecosystems. The Act placed a premium on accurate emissions monitoring to manage the program, rather than environmental monitoring (unlike the provisions of the Act to manage criteria pollutants, which is discussed later in this overview). In Europe, the 1994 Sulfur Dioxide Protocol to the 1979 Convention on Long-Range Transport of Air Pollutants (LRTAP) employed the concept of “critical loads” to manage emissions. A critical load is a quantitative estimate of the atmospheric load of the pollutant below which significant harm is not expected to sensitive elements of the environment according to present knowledge. Instead of reducing emissions irrespective of downwind harm, critical loads of sulfate are established for downwind ecosystems, and a model is used to determine the required emission reductions upwind. A review of the most recent manual for determining critical loads reveals that the approaches rely more heavily on modeling and the results of field and laboratory experiments, than on monitoring data.[12]

Acid precipitation (and some of its effects) continue to be monitored systematically in North America and Europe (Chap. by Kutz), and monitoring certainly has been widely used in *evaluating policy and program performance.* Whether such evaluation has resulted in mid-course corrections in the control of acid precipitation is harder to assess. The first phase of controls on sulfur and nitrogen emissions under the CAA in the U.S. was not completed until 1995. At that time, the U.S. Environmental Protection Agency (EPA) prepared a report required by Congress to determine whether the CAA adequately protect sensitive areas of the U.S.[13] Limited monitoring data suggested that the capacity of forests to absorb most of the reactive nitrogen in precipitation (and thus to prevent acidification of soils and runoff) in the U.S. and Europe was being exceeded. Monitoring data from the acid-sensitive lakes of the Adirondack region, however, showed no discernable pattern over 12 years. Biogeochemical models suggested that further reductions in nitrogen emissions would be required, but due to uncertainties in the models, the EPA concluded that no new recommendations were warranted at the time. The science advisory board that reviewed the report concluded that without direct monitoring evidence, it is unlikely that incremental regulations would be based on modeling evidence alone.

Do the monitoring data suggest additional reductions are needed? Phase 2 of the sulfate emissions reductions in the U.S. began in 1996. Monitoring of precipitation in the U.S. and Canada has since shown widespread reductions in sulfate since 1995, and monitoring of lakes in the U.S. has revealed recovery of one-third of acid lakes to non-acidic status, but there have been no significant trends in nitrate in precipitation.[14-15] In 1998, the EPA enacted new controls on nitrogen oxide emissions that will substantially reduce nitrate in precipitation, but the primary purpose was to control regional ozone. In 2002 proposed “Clear Skies” legislation that would further reduce acid precipitation, but again as a beneficial side effect of reductions in ozone and particulate matter, which are thought to have substantial health effects.[16] Monitoring therefore has demonstrated that emissions reductions have had beneficial effects, but apparently has not led directly to modifications in controls.

Stratospheric Ozone Depletion

The scientific and policy history of the stratospheric ozone depletion problem has been described by Albritton,[17] Morrisette,[18]Abbat and Molina,[19] Rowlands,[20]and Bendick[21] In 1974, Molina and Rowland hypothesized that chlorofluorcarbons (CFCs) could catalyze the reduction of ozone in the stratosphere, leading to an increase in ultraviolet B (UV-B) radiation at the Earth’s surface. During the early 1970s, CFCs used as aerosol propellants constituted over 50 percent of total CFC consumption in the United States. Widespread press coverage raised public concerns that the increase in UV-B radiation would lead to an increase in skin cancers. A consumer boycott followed in the U.S., and in 1977 the United Nations Environmental Program developed a non-binding international effort to conduct research and monitoring on the ozone depletion problem, Non-essential uses of CFCs in aerosol containers were banned in the Canada, the U.S., and a few European countries in 1978. This particular use of CFCs was reduced in the U.S. by approximately 95 percent, cutting total U.S. consumption of CFCs by nearly half. In the years following the aerosol ban, CFC use increased significantly in the refrigeration, foam and solvent-using electronics industries and by 1985, CFC use in the U.S. had surpassed pre-1974 levels and represented 29 percent of global CFC usage.

Under the Clean Air Act of 1977, the EPA published a notice of advanced rulemaking in 1980 to further restrict the manufacture and use of aerosols, but didn't act on it.[22] On the international front, the 1985 Vienna Convention for the Protection of the Ozone Layer continued to pursue a non-binding approach to international controls on CFCs, and plans were made for the next international meeting in Montreal two years later. Then, in late1985, an ozone "hole" was reported over Antarctica. Based on monitoring data from a ground network of "Dobson" monitors and confirmed by satellite measurements, the "hole" was actually a 35% depletion in stratospheric ozone over Antarctica since 1957, showing a trend of accelerating loss since the mid-1970s. Two years later, in 1987, the Montreal Protocol was signed, committing 23 nations to a reduction of 50 percent of the most damaging "Class I" products (four CFCs and three halons, which contain bromine instead of chlorine) by 1998.

How big a role did monitoring data play in the 1978 ban and the Montreal Protocol? Daniel

Albritton, who co-chaired the UNEP's scientific assessments of stratospheric ozone and was a key player at the meeting, recalled that as the Montreal Protocol was being negotiated, the ozone hole had not been explicitly linked to CFCs, and it was not predicted by the atmospheric models being used at the time, and therefore was not explicitly considered.[17] With respect to monitoring data from a ground-based network of Dobson spectrophotometers begun during the International Geophysical Year in 1958 and from a Solar Backscatter UltraViolet (SBUV) instrument launched into orbit in 1978, he wrote that, "the observations, although they suggested a decrease whose rough magnitude was similar to that predicted, were not considered entirely believable. Theory, on the other hand, could justify some strong predictions." The theoretical models, however, predicted that without substantial reductions of CFC uses, there was a substantial risk of UV-B increases at high latitudes, and also of global warming. Richard Benedick, the chief U.S. negotiator on the Montreal Protocol, later said that the most extraordinary aspect of the treaty was that it imposed substantial costs against unproven dangers, "that rested on scientific theories rather than on firm data."[21] That situation was about to change.

Shortly after the Montreal Protocol was signed in 1987, an international team of scientists linked the ozone hole over Antarctica to CFCs. They later presented monitoring data from the Total Ozone Mapping Spectrometer (a satellite instrument) that showed that, between 1979 and 1987, stratospheric ozone had decreased worldwide by 0.4% per year, a larger decline then anticipated at the time the Protocol was signed. Considering these findings, the London Convention in1990 phased out production and importation of all CFCs by 2000, and the U.S. EPA proposed a conforming regulation in 1991.[22] Subsequent monitoring revealed that in January of 1992, stratospheric ozone had dipped as much as 20 percent in the Northern Hemisphere and as much as 45 percent for a few days over Russia. Later that year, the Copenhagen Convention in 1992 moved up the date for phase-out of the Class I compounds to Jan 1, 1996, and added two other compounds to the list. By 1993, 107 nations had become parties to the protocol.

Based on the remarks of Albritton and Benedick, key players at the Montreal meeting, we must conclude that monitoring data took a back seat to theory in *identifying the problem* of stratospheric ozone depletion. It is fairly clear, however, that the monitoring data became more important in focusing attention on the immediacy of the problem, as targets and deadlines for phase-out of the Class I substances were tightened in the 1990 and 1992 amendments. Courtney Riordan, EPA's research director in the area, recalls Robert Watson of the White House Office of Science and Technology Policy briefing Administration Executives and Congress with a dramatic visualization of the ozone hole.[23] Also important in *analyzing the problem*, but not receiving as much attention in the overviews, were monitoring data from a worldwide network begun in 1978 that showed increasing levels of CFC's and other halocarbons in the background atmosphere over the period 1978-1992.[24] Morrisette argues that the ozone hole was a tangible, measurable impact that galvanized public opinion, and thus influenced the outcome in Montreal,[18] and coverage of the issue in the international popular press peaked in the late 1980s and early 1990s,[7] thus likely increasing public pressure to further tighten the deadlines in London and Copenhagen.

We can safely say that monitoring played a key role not only in *analyzing* the stratospheric ozone deletion problem, but in *formulating national and international CFC policy and setting priorities*, especially with respect to extent and rate of phase-outs. The compounds to be included in the phase-outs depend primarily on their Ozone Depletion Potentials (ODPs), which determine whether they are included in Class I or Class II (the latter have much lower ODPs, and are being used as substitutes for Class I compounds until they, too are phased out). Determination of ODPs is primarily based on theory and laboratory experiments, but an alternative empirical approach does utilize field observations and monitoring data.[25] The rate and extent of phase-outs appear from the overview papers to be primarily a function of the perceived need to do as much as possible, and as quickly; the technological and economic feasibility, and the modeling results that forecast that the planned targets will significantly reduce the concentrations of ozone-depleting substances in the stratosphere.

The role of monitoring in *executing policy and programs* with respect to CFCs is apparently modest. Compliance with the Protocol and U.S. regulations relies on manufacturing, recycling, destruction, and import data, rather than on achieving an ambient standard. Monitoring plays a key role, however, in *evaluating CFC policy and program performance*. Monitoring of stratospheric ozone, background levels of CFCs and other halocarbons in the atmosphere, and more recently UV-B levels at the Earth's surface are analyzed and reassessed by international teams of scientists on a regular basis. The most recent report showed that ozone levels over the

Antarctic have continued to decline, and now are approximately 50 percent of the 1957 levels, and that levels continue to decline, but at a smaller rate, over many cities in mid-latitudes.[26] It also showed that ozone-depleting compounds in the stratosphere peaked in 1994, and declined by about 5 percent through mid-2000 (expressed as the equivalent effective stratospheric chlorine), and that based on monitoring of hydrogen chloride and chlorine nitrate total column absorbance measurements, chlorine stopped increasing in 1997-1998 and has remained fairly constant since. The report concludes that monitored concentrations of ozone-depleting gases in the atmosphere are in line with expectations from the fully modified and adjusted Montreal Protocol, and that accelerating the rate or extent of phase-outs at this time would provide only modest improvements in the rate of ozone recovery to pre-1980 levels in the stratosphere. Therefore, no significant modifications of policy appear to be indicated by the monitoring data.

Global Climate Change

The scientific and policy history of the global climate issue has been described by many authors, but this discussion relies heavily on Hecht and Tirpak,[27] Keeling,[28] Pielke[29], Leaf,[30] and Clark et al.[7] The ideas that burning coal could increase carbon dioxide (CO_2) in the atmosphere enough to raise the global temperature significantly was first raised in 1896, but it was not until 1957 that Revelle and Seuss published a paper that drew scientists attention to the “large-scale geophysical experiment” that humans were conducting with fossil fuel combustion. The global climate change debate since then has been driven primarily by modeling (amongst great scientific debate) changes in climate as a result of changing concentrations of carbon dioxide (CO_2), and other “greenhouse” gases, and by the effects of such changes and the economic costs of decreasing greenhouse gas emissions or mitigating the effects.

In the midst of the scientific debate about theory, however, monitoring played an important role in demonstrating that concentrations of greenhouse gases and global temperatures have continued to increase over the course of the scientific and policy debate, thus keeping the pressure on scientists and policy-makers, alike. In the early 1950s, the scientific literature suggested that CO_2 concentrations were highly variable with latitude and time of day, which would make the determination of global trends very difficult. A young scientist named Charles Keeling made measurements of CO_2 on samples collected several times a day at a number of locations from Canada to South America and found, on the contrary, that daytime concentrations were all close to 310 ppm. His interest led to the beginning of a long-term data series of CO_2 measurements at the peak of Mauna Loa in Hawaii, the Antarctic, and two other locations, as part of the International Geophysical Year (IGY) in 1957. Keeling published his first results in 1960, showing a seasonal cycle in the Northern Hemisphere associated with plant growth that diminishes toward the equator, and a possible global year to year increase. At the time, the year-by-year rise appeared consistent with the amount of CO_2 from industrial activity. This later turned out to overestimate the importance of industrial emissions, because the measurements were taken during an El Nino event, which tends to increase the level in the atmosphere.

In 1969, Keeling reported that the CO_2 data from Mauna Loa now showed definite upward trend of approximately 6 ppm over 10 years, with a strong seasonal cycle, and speculated that these data empirically supported Revelle's concerns about the potential for global warming. He published a subsequent paper in 1972 that showed that the trend line was increasing in slope (shown later to be the result of the periodic ENSO) and was consistent with some very simple compartmental models that showed that approximately half of the CO_2 was being absorbed into the ocean. Several international meetings were held on the global warming issue in the 1970s, culminating in the first World Climate Conference in organized by the World Meteorological Organization (WMO) in Geneva in 1979. Although the analysis was published later, the late1970s included a period of extremely unusual winters,[31] and there was concern at the time that the Earth may actually be heading into a period of glaciation, rather than warming.

Research expenditures increased, and in 1985 the U.S. Department of Energy published a report concluding that some effects of global warming may already have been evident: CO_2 concentrations in the atmosphere (including Keeling's Mauna Loa data) continued to increase, as did Northern hemisphere land temperatures, sea surface temperatures, and sea level.[32] The report concluded that if emissions of greenhouse gases continued as expected, monitoring would either confirm the results predicted by the models or show that they "require extensive reconsideration." The United Nations Environment Programme (UNEP) published a conference report in 1986 that noted that monitoring showed that other important greenhouse gases (methane, CFCs and tropospheric ozone) were also increasing globally, further increasing the risk of climate change. UNEP pressured the U.S. to support a convention to control greenhouse gases and to contribute to an international assessment effort, and the Climate Protection Act of

1987 was signed into law, requiring the U.S. EPA and DOE to develop policy options for dealing with the problem. In 1988, NASA scientist James Hansen testified to a Senate committee that he was 99% certain that global warming was underway. Hecht and Tirpack noted that monitoring data showed that at the time of Hansen's testimony, the world was suffering through one of the warmest years thus far on record, and that CO_2 concentrations had risen to 350 ppm.[27]

The International Governmental Panel on Climate Change (IPCC), jointly created by WMO and UNEP to bring together a global network of over 2,000 scientists to inventory current scientific knowledge the climate system, the effects of climate change, and possible response strategies, published its first report in 1990. Two years later, the Framework Convention on Climate Change was signed, committing the signatories to emissions reductions, but without required targets or timetables. The next IPCC scientific assessment of 1995 led with monitoring data that showed that greenhouse gas concentrations, mean surface temperatures, and sea levels had continued to rise.[33] Two years after *that* report, in 1997, more than 180 countries ratified the Kyoto Protocol, which *did* contain targets and timetables. The targets were not driven by attempts to achieve particular greenhouse gas levels, but by what was economically feasible for the signatories, and compliance has not been sufficient to expect a significant change in either CO_2 concentrations or temperatures. We thus conclude that monitoring has not played a key role in global climate policy-making beyond it's key role in *identification and analysis of the problem* that forced international action.

Criteria Air Pollutants in the U.S.A.

Title I of the Clean Air Act Amendments of 1990 provide one of the few examples we have of the importance of monitoring in *executing policy and managing programs.* Criteria pollutants are explicitly identified in the CAAA, and include lead, ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide (NOX), and particulate matter (PM).[34] Primary National Ambient Air Quality Standards (NAAQS) are required to be set at an ambient level determined by EPA to be protective of human health regardless of costs or current ambient levels. Each State develops a State Implementation Plan (SIP) that allows it to determine how to best achieve the NAAQS by controlling the various sources within the State. States are required to monitor the concentrations of these pollutants according to strict protocols at more than 18,000 sites in the NAMS/SLAMS network (Chap by Kutz/Bradley). If the concentrations of any of these pollutants exceed their respective standards in a particular area, then the area is determined to be in non-attainment, and the SIP must be adjusted to achieve attainment in a reasonable period of time. An area in non-attainment may even lose highway construction grants from the Federal government. Thus there is a direct feedback between monitoring and controls on pollutant sources.

Although monitoring does not play a direct role in *establishing targets* for the NAAQS themselves, it can play a role in setting emissions reductions targets to achieve the NAAQS, as well as *setting priorities* for which NAAQS get the greatest attention. NAAQS are required under the CAAA to be reviewed every five years, but the EPA frequently falls behind schedule. In the early 1990s, a series of statistical analysis or mortality data and PM data from the

NAMS/SLAMS network indicated that non-attainment of the current NAAQS for PM_{10} (the fraction of particulate matter smaller than 10 micrometers) may account for more than 60,000 deaths in the U.S. annually.[35] These results received considerable press coverage, and a public interest group sued the EPA to promptly review the NAAQS. At the time, the available toxicological data did not seem to explain or support this finding, but eventually the EPA did revise the PM NAAQS, including the addition of a new NAAQS for an even smaller particulate fraction ($PM_{2.5}$), again that was largely identified though epidemiological studies.[36]

The criteria pollutants also offer examples of the role of monitoring in *evaluating policy and program performance*. Each year, the EPA publishes a report on the status and trends in air quality. The most recent report concluded that, despite progress approximately 133 million people live in counties where monitored air in 2001 exceeded at least one of the NAAQS, usually because of ozone and particulate matter.[37] Consequently, the EPA was proposing rules to reduce emissions from certain road, non-road mobile, and stationary combustion sources. Moreover, the EPA also had submitted to Congress, "Clear Skies" legislation that, if enacted, would mandate reductions of particle- and ozone-forming compounds from power generators by 70 percent from current levels through a nationwide cap and trade program. The EPA was not only more aggressively pursuing rulemakings under the existing statute, but seeking new statutory authority based on monitoring data that showed the current rules were not achieving the NAAQS. Furthermore, emissions monitoring data for both sulfur dioxide and NOX showed that cap-and-trade approaches were not leading to large regional shifts in emissions, which strengthened EPA's commitment to a cap-and-trade approach for the three pollutants covered by the proposed new legislation.[38]

Although monitoring does not lead directly to the establishment of NAAQS, two examples show how it can nonetheless be important in other air quality regulations. The case for lead (a criteria pollutant) is nicely discussed in a volume edited by Ratcliff.[39] Careful monitoring of atmospheric background lead in the atmosphere at Mauna Loa in the 1970s showed that most atmospheric lead must come from tetraethyl lead in gasoline, as opposed to some global geochemical source. Monitoring of human blood lead levels also showed a close correlation with ambient levels of lead in the atmosphere in the U.S. over the 1970s. These observations likely played a key role in the decision to ban lead in gasoline in the U.S. in 1986. Likewise, a decision by the EPA in 2000 to regulate mercury emissions from power plants[40] relies on a risk assessment that hinges on an extensive program monitoring mercury in fish tissue in the 1970s and 1980s.[41]

Water Quality in the U.S.A.

In an influential paper in 1971, Wolman concluded that increasing pressures on U.S. rivers may have been outstripping then current investments in water quality management, but that water quality monitoring was inadequate to determine if things were getting better or worse, or to determine the level and types of expenditures needed.[42] The next year, the Federal Water Pollution Control Act Amendments of 1972 were drafted so that water quality monitoring would drive the nation's entire approach to water quality management, including assessment, standard setting, planning, discharge permitting, construction funding, and accountability. Savage provides an excellent analysis.[43] Under the Act, each State would survey its waters, and assign designated uses (e.g., fishing, body contact, water supply) to each one. Water quality standards to achieve each designated use would be set and re-evaluated periodically. Point-source discharges (e.g., wastewater treatment plants) would receive permits that would ensure that water quality standards were not exceeded in the receiving water body at the point of discharge. If water quality monitoring revealed that a water body was still not achieving standards, the State then must determine the total maximum daily load (TMDL) that would be allowable for each pollutant that was causing the violation of the standard, and develop a watershed management plan to insure that the TMDLs were not exceeded. The plan could include management of non-point sources pollution that were otherwise not required to have a discharge permit. Every two years, the States would report to the EPA on the extent and causes of non-attainment of water quality standards, and Federal funding for construction of wastewater treatment plants and watershed management would be tied to the extent of waters not achieving standards in each State. Monitoring also would be used to re-assess both the designated uses for each water body, and the adequacy of the standards to protect each designated use. The system thus would address all four policy purposes for monitoring.

It is likely that all of the States use their water quality monitoring programs *to identify and analyze problems*, to *formulate policy and set goals and priorities*, to *execute and manage their water quality control programs*, and *to evaluate their performance*, but these decisions are not conveniently documented in the literature. Adequate funding to support the level of monitoring required to make the system work as planned was never made available, and the system still suffers from the consequences at the national policy level. In 2000, the U.S. General Accounting Office reported that the States had “little of the information needed to assess the quality of their waters and, in particular, to those that are impaired - a particularly serious problem, given resources needed to address such impairments.” [44] Although this statement recalls that of Wolman three decades earlier, the EPA and the States have made progress in the last few years in improving monitoring designs (Chap. by Messer) and in providing additional funding to execute them.[43]

In addition to the water quality monitoring by the States, the U.S, Government also conducts or sponsors its own water quality monitoring programs. We have already seen monitoring of lakes sponsored by EPA has revealed that considerable recovery from acidic status has occurred as a result of SO_2 emissions reductions, but that additional controls will be needed to further reduce the number of acidic lakes.[37] The monitoring of mercury in fish noted previously was conducted by the U.S. Fish and Wildlife Service.[45] The U.S. Geological Survey NASQAN program (Chap.by Kutz/Bradley) has been particularly instrumental in tracking long term patterns and trends in the export of certain chemicals from watersheds, and for example has identified tremendous increases in the export of nitrogen from the Mississippi River watershed over the past four decades, which is contributing to a very large “dead zone” of anoxic water in the Gulf of Mexico.[46] An Action Plan describing a national strategy to reduce the frequency, duration, size, and degree of oxygen depletion of the hypoxic zone of the northern Gulf of Mexico was submitted as a Report to Congress on January 18, 2001, but there are as yet no enforceable targets or deadlines.[47] Again, most such monitoring data sets seem to play the largest policy role in *identifying and analyzing problems*.

Environmental "Report Cards"

If monitoring and assessment has contributed significantly to policy decisions, why isn't the public more aware of the importance of monitoring data? There here has been growing international attention to providing "report cards" to the public on trends in the condition of the environment, [48] but the idea is certainly not a new one. The National Environmental Policy Act of 1969, requires the President to report annually to Congress on the state and condition of the environment, on current and foreseeable trends, on the adequacy of available resources, on the progress of programs aimed at protecting the environment, and on a program for remedying any deficiencies in these programs, including recommendations for any new legislation.[49] Being the foremost item on the list, it would therefore seem that Congress intended that environmental monitoring data would play a key role in guiding national environmental policy. A review of the annual reports, however, reveals substantially more data on polluting activities (e.g., water withdrawals, pollutant emissions, vehicle miles traveled) and administrative programs (e.g., permits written, expenditures on control or clean-up), than on trends in the condition of the environment itself. The 21st Annual Report of 1990, for example, shows little environmental monitoring data other than those described in the examples in this overview.[50] In the same year, the Administrator of the EPA wrote that he thought that the EPA did an exemplary job of protecting public health and the quality of the environment, but concluded, "Now the bad news. I can't prove it."[51]

Only slight progress has been made since 1990. As of 2003, the European Environmental Agency (EEA) maintain data on 92 environmental indicators, of which only 16 involved environmental monitoring,[52] an eclectic mix that includes human exposure to traffic noise and ozone, pollutants in rivers, fragmentation in grasslands, and fisheries stocks. At the global scale, the United Nations Environment Programme developed its Global Environment Outlook (GEO) project in response to the environmental reporting requirements of Agenda 21 and to a UNEP Governing Council decision in May 1995 requesting the production of a comprehensive global state of the environment report. In order to prepare the second report in 2000, the GEO Data Working Group identified approximately 90 variables associated with data sets from 202 countries.[53] Analysis by the group identified so many inconsistencies and other quality problems with these data that in the final report, the 90 variables were reduced to 15, none of which actually represented measures of the "state" of the environment. The most recent GEO report, *Global Environmental Outlook 3*, includes a web-based data portal with access to over 400 environmental data sets, but only lists a few state variables, including the extent of degradation of agricultural land, extent of deforestation, fish catch, and the number of endangered species of invertebrates.[54]

In the U.S.A., the Government Performance and Results Act of 1993 (GPRA) now requires all federal agencies to develop annual performance plans, to establish performance goals, and to express those goals in an objective, quantifiable, and measurable form.[55] The Act has provided considerable impetus for the EPA and other agencies with environmental missions to identify indicators of program performance to correspond to their GPRA goals. Some of the indicators are associated with monitoring data on the actual state of the environment, but the numbers so far have been modest. The Heinz Center, working with a group of public and private sector partners, developed a report entitled *The State of the Nation's Ecosystems.*[56] The report includes 103 indicators, of which only 33 were judged by the authors to have adequate data for national reporting. Even more recently, *The U.S. Environmental Protection Agency Report on the Environment* included 112 indicators of the state of the environment (exclusive of public health indicators), of which only 21 were deemed adequate for national reporting, based on the availability and representativeness of national environmental monitoring data.[57] The majority of the 21 indicators relied on data from the sources identified in the examples in this overview, but a number of new ones involved land cover and land use indicators derived from globally consistent satellite data. This situation is expected to improve in the next report. The Forest Health Monitoring and Forest Inventory and Analysis programs of the U.S.D.A. Forest Service are on the verge of providing nationwide data on ecological condition of forests across the U.S.A. (Chap. by Riiters), and the EPA Environmental Monitoring and Assessment Program is doing the same for estuaries nationwide (Chap. by McDonald) and conducting regional pilot projects on streams and rivers.

It is not clear exactly how or whether environmental report cards like those discussed above (and others published by non-governmental environmental organizations) have affected policy-making to the extent seen for acid rain, stratospheric ozone depletion, or global climate change. A primary intention of all of these projects is to provide information about environmental trends to the attentive public (including lawmakers), who will in turn put pressure on environmental agencies to take any necessary corrective actions. Of course it is seldom quite that simple. For example, Healy and Ascher explain how a Congressionally mandated increase in monitoring to support public participation in forest management decisions resulted in assessment becoming such a complex task that the result was to "shift power away from non-expert actors, undermine rights arguments, polarize debates over appropriate resource use, and delay timely decision-making." [58] Congressman Brown also questioned whether the truly objective data needed to make policy ever exist, in the sense that experts from opposing sides in environmental debates always seem to claim that the data support their position, but concluded that the most promising roles for environmental data were in identifying problems and evaluating outcomes in order to provide mid-course corrections in policy.[4] On balance, it still seems better to have data than not, but unless and until more monitoring data become available, all these points will remain moot.

Summary and Conclusions

We have seen in the examples in this chapter that monitoring and assessment can play a key role in any or all of the four areas of policy-making identified at the beginning of this overview. The most frequent role in the examples was *identifying and analyzing environmental problems,* followed by *evaluating policy and program performance.* Key roles in *formulating policy and setting goals and priorities* and *executing policy and managing programs* were less frequent, but the examples for criteria air pollutants and water quality management in the U.S.A. show how important these roles can be for integrated policy approaches that are built around a central core of monitoring and assessment. These results are probably reasonably representative of air and water-related policy making based on ambient environmental monitoring. If monitoring of pollutant emissions and pollution control actions had been included, the importance of monitoring in *setting goals and executing and managing programs* would increase substantially. Examples from other countries or other environmental policy areas (e.g., natural resource management) may also have revealed different patterns. As we look to the future, growth of interest in environmental report cards, accountability legislation like the Government Performance and Results Act of 1993, and shifts between receptor-oriented regulatory strategies such as "critical loads" and emissions-oriented strategies such as "cap-and-trade" also could shift the future balance of the roles monitoring and assessment play in environmental policy-making.

In any case, this overview should make clear why monitoring and assessment can and should be so important to environmental policy-making. Recognition of this importance is the key to both designing and maintaining regional and global monitoring networks. Too often, monitoring is seen as an expensive and less-worthy drain on funding that could otherwise be spent on research or pollution control. The examples in this overview should demonstrate otherwise: that monitoring, designed with a view toward explicitly supporting one or more of the four types of policy decisions, can lead to better and more efficient environmental policies and programs. This fact makes the contributions in this book on environmental monitoring all the more important.

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