ES&T
OUTLOOK

Acid precipitation

Acid rain has a detrimental effect on fish and other wildlife, on man-made structures, and on water supplies. Present trends indicate that the emissions producing acid rain are likely to increase

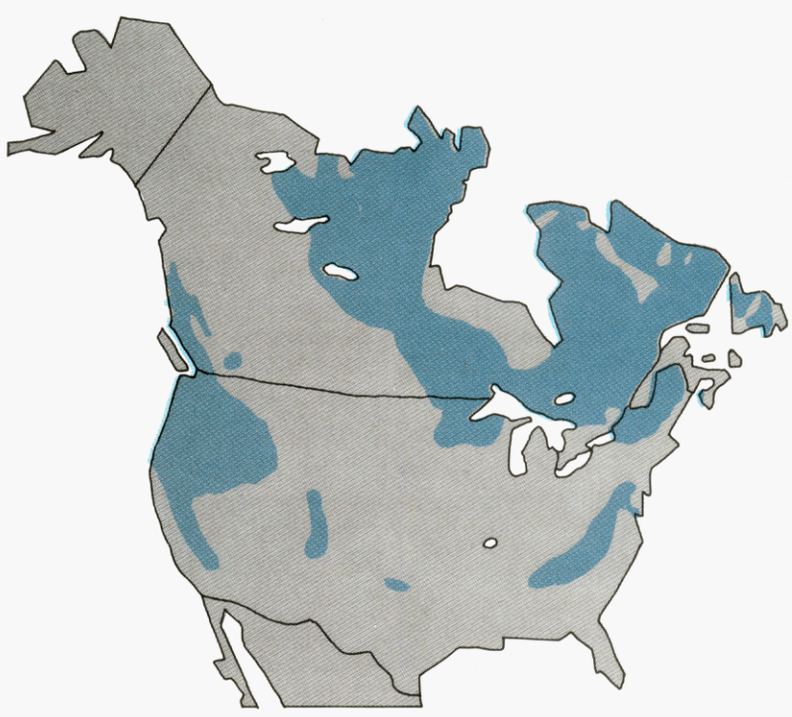
Although it was not recognized as a problem in the U.S. until quite recently, acid precipitation, which consists of both wet acidic precipitation and dry deposition of acid particles and acid-forming gases, has been a growing phenomenon in the U.S. and Canada for decades. At the acid rain/fisheries symposium held at Cornell University in early August, Ellis Cowling of the North Carolina State University at Raleigh said that two-thirds of the land area of the U.S. and more than one-half the land area of Canada are receiving acid precipitation.

The pH of natural rainfall can vary, but normal or background pH is usually about 5.6, that of distilled water in equilibrium with atmospheric carbon dioxide. Recent measurements of wet deposition show that significant portions of Ontario, Quebec, and the eastern U.S. receive precipitation that is on the average about 40 times more acidic than background. The zone of maximum acidity is an oval area that stretches from Ohio and Pennsylvania up into southern Ontario.

When acid precipitation falls on areas that are underlain by limestone or other carbonate rock, it is neutralized (buffered) by this mineral and does not cause the lakes and streams to become acidified. However, when acid rain falls on "sensitive" soils—soils lacking calcium carbonate which are often thin and underlain by granitic bedrock—the acid is not buffered. The rainwater remains acidic as it runs over and through the soil into the streams and lakes. The sensitive areas of the U.S. and Canada include some of the most unusual, unspoiled, and biologically diverse environments in North America.

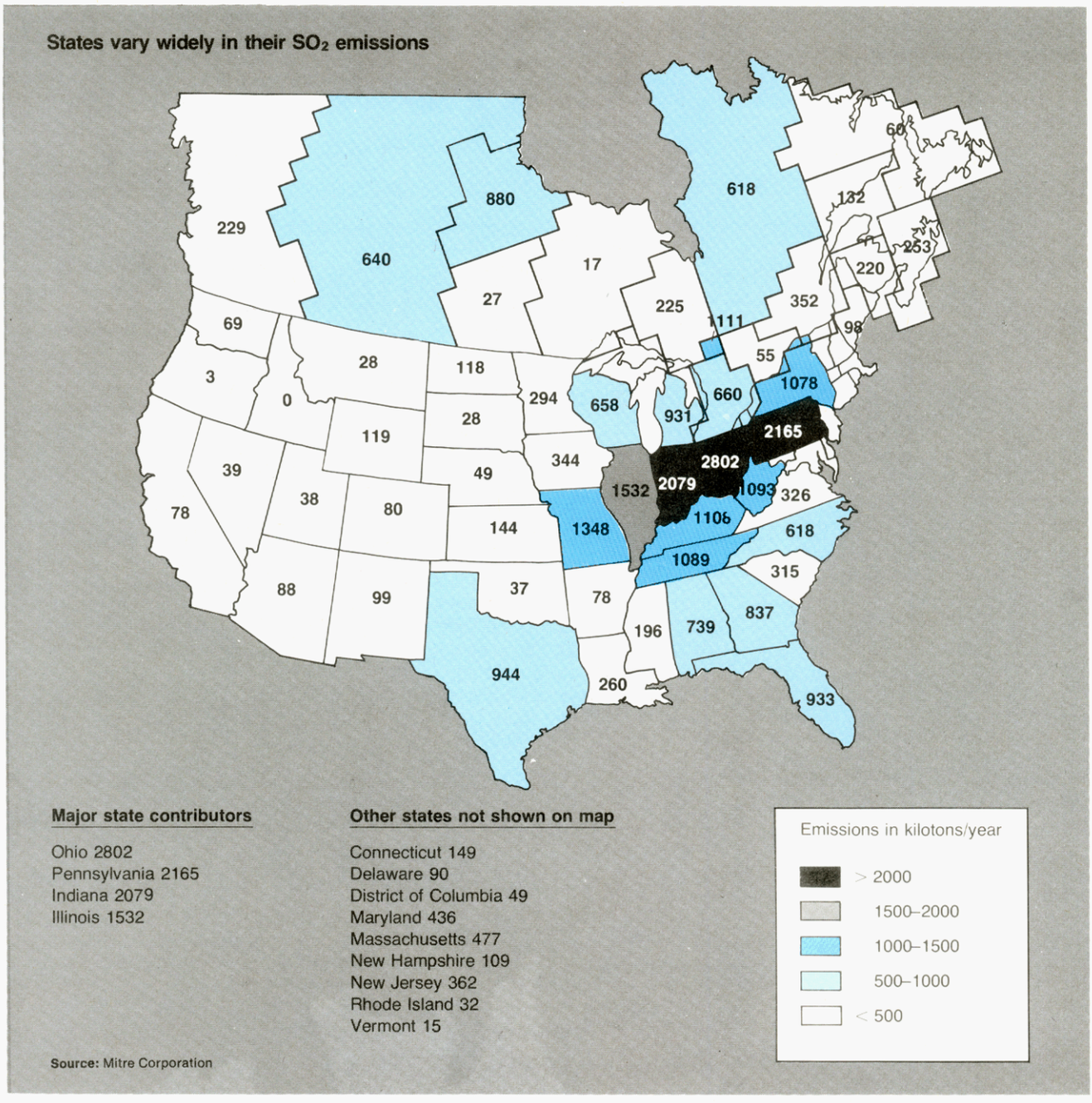
In the Adirondack region of the U.S., where acid deposition has been intense, more than 100 lakes which formerly supported brook trout are now devoid of any fish due to the acidity of the water, and many more lakes not yet fishless are being acidified. In Nova Scotia there are at least nine acidified rivers that no longer allow salmon to reproduce, and more than 140 lakes in central Canada are so acidified that they cannot maintain fish life. Thousands of other lakes that lie in sensitive regions could become acidified in the near future if emissions are not reduced. Gary Glass of the EPA Duluth laboratory said at the symposium, "The scope of the acid-

North American areas sensitive[a] to acid precipitation



[a]Sensitive areas are those that lack limestone or other carbonate rock.
Source: James N. Galloway and Ellis B. Cowling, *Journal of the Air Pollution Control Association*, Vol. 28, No. 3, 1978

0013-936X/81/0915-1119$01.25/0



rain problem is much larger than we previously thought. We were most surprised by the *size* of the area that is affected by acid precipitation."

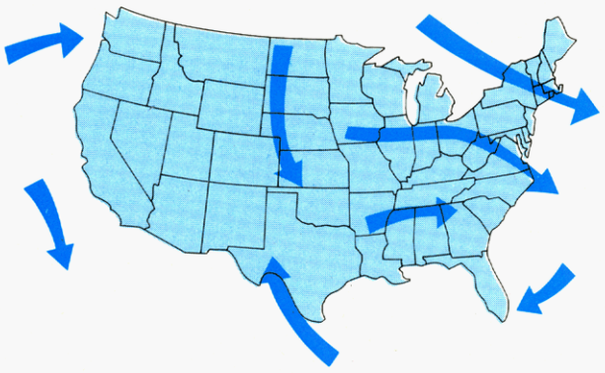
Sources

Acid deposition is caused primarily by sulfur and nitrogen oxide emissions that are converted to sulfuric acid and nitric acid in the atmosphere and in the soil. Ammonium sulfate and nitrate, formed from combinations of oxides of sulfur, nitrogen, and ammonia, also play a part. These ammonium compounds themselves are not acidic but can cause acidification of soils when taken up by plants or modified by soil microorganisms. It is estimated that approximately half the acidic material deposited is in a dry form—gases and particles—especially in regions close to emission sources; the remainder is washed out of the atmosphere by rain and snow. Measurements of dry deposition are difficult and not routinely made. Therefore, much less is known about the depositional patterns of dry acidic material.

The primary sources of sulfur oxides, which consist mainly of SO_2, are the burning of coal and petroleum products and ore smelting. In the U.S., about two-thirds of the SO_2 is produced by the electric utilities. Coal burning supplies most of the SO_2, and it is interesting to note that the electrical energy capacity provided by coal in this country rose from less than 26 000 MW in 1930 to over 230 000 MW in 1980. Industry accounts for another 27% of SO_2 emissions and, in contrast to those from utilities, these emissions have been reduced from 11 to 7 million tons in the last 20 years. Although the largest part of the nitrogen oxide (NO_x) emissions are produced by transportation (40%), the electric utilities and other industries combined supply 55%.

SO_2 and NO_x can have an atmospheric residence time of several days and can be carried hundreds, even thousands, of miles before they are brought down as acids in precipitation or deposited as dry particles or gases. When SO_2 and NO_x are emitted close to the ground, they are usually deposited quickly. When they are released by tall stacks, which have been used only in the last two decades, these

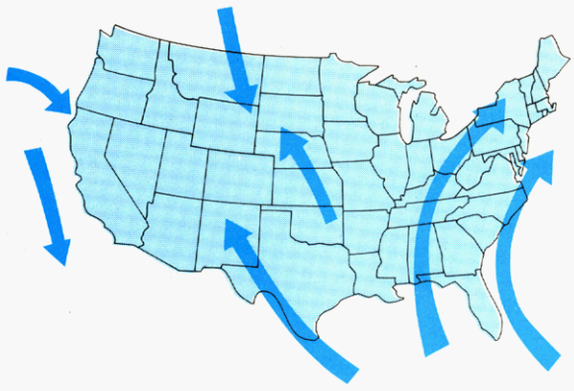
During January, the winds tend to carry the emissions in the East out to sea . . .[a]



[a]Mean resultant surface winds for January: Resultant wind is the vectorial average of all wind directions and speed during the month.

Source: Climatological Atlas of the United States

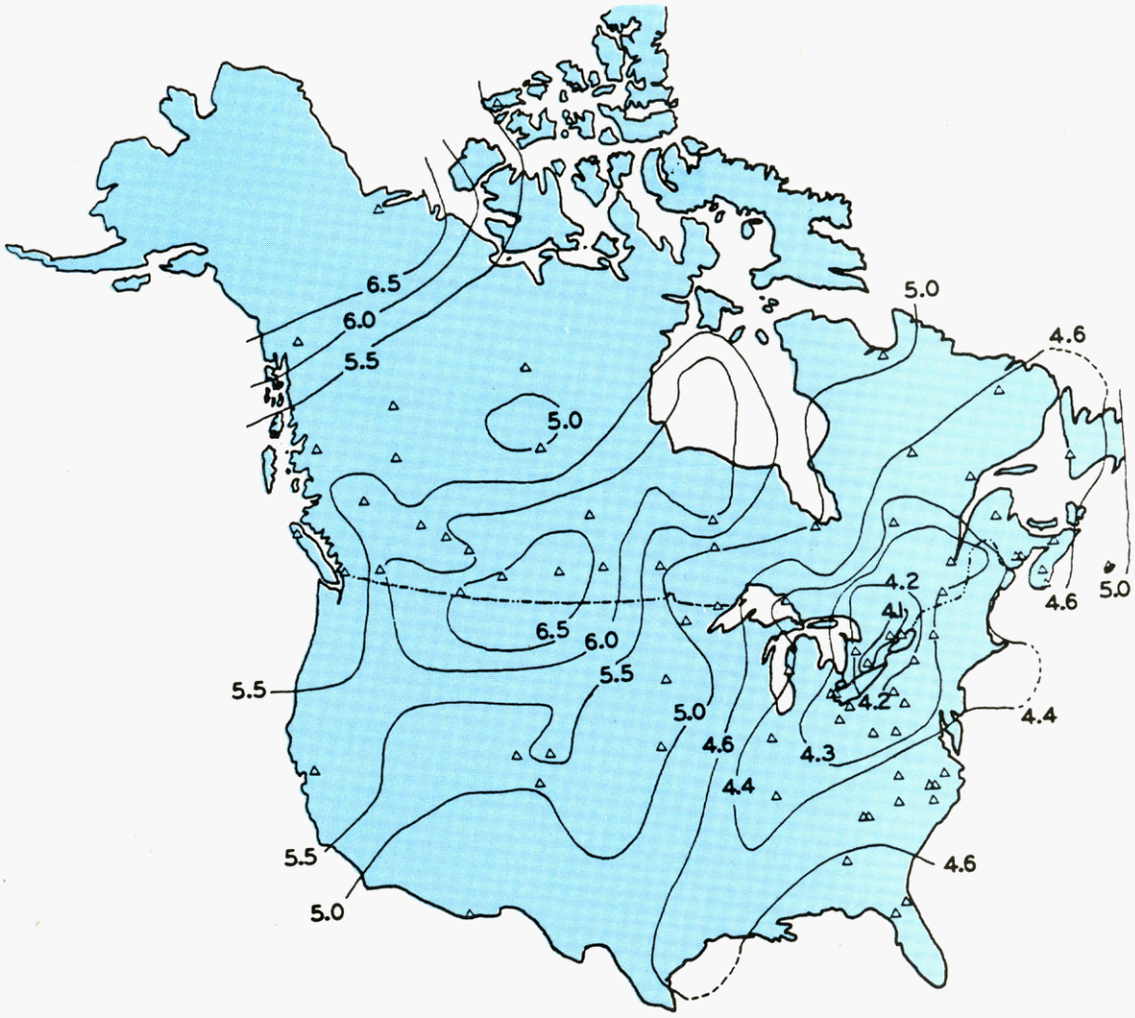
. . . but in July more of the emissions are carried northward . . .[b]



[b]Mean resultant surface winds for July: Resultant wind is the vectorial average of all wind directions and speed during the month.

Source: Climatological Atlas of the United States

. . . resulting in precipitation with a low average annual pH over eastern North America



Volume weighted average pH of precipitation for North America, April 1979–March 1980
73 reporting sites (△) from the NADP and CANSAP precipitation monitoring networks

Source: Glass and Brydges, 1981

pollutants can be transported by the wind for several days. They are carried wherever the wind blows, in many cases to sensitive regions such as the Adirondacks and northern Wisconsin and Minnesota. It is estimated that two-thirds of the sulfur emitted from eastern North America is deposited there, and the remainder is transported out over and into the Atlantic Ocean.

The relative importance of sulfur and nitrogen oxides is a subject that is being studied intensively at this time. However, the prevailing view is that sulfur oxides are probably a far more important cause of the acid precipitation problem than nitrogen oxides. In the complex chemical processes that are involved in plant growth, the hydrogen ion accompanying the nitrate ion appears to react along with the nitrate ion to form new plant cells so that little or no net acidification occurs. The hydrogen ion associated with the sulfate ion, on the other hand, eventually exchanges with calcium and other cations in the soil. This process leaches out the cation nutrients and leaves the hydrogen ions behind to acidify the soil and water contained within the watershed.

However, during periods of rapid snowmelt, nitrates and sulfates that have accumulated in the snow throughout the winter pass directly into the lakes as acids without coming into prolonged contact with vegetation or soil. Also, in areas where there is little vegetation, NO_x emissions can, of course, cause acidification, and NO_x is a precursor to ozone, which has a well-established negative effect on plants.

It has been argued that since there are both natural and man-made sources of acid-causing emissions, it is impossible to tell which is responsible for acid rain. Although the relative importance of anthropogenic and natural emissions of SO_2 is still highly uncertain on a worldwide scale, anthropogenic emissions of SO_2 are known to be as much as 100 times greater than natural emissions in North America. Moreover, recent analysis has concluded that, in North America, anthropogenic sources supply substantially more NO_x than natural sources, even though global emissions are of the same order of magnitude.

Effects on aquatic life

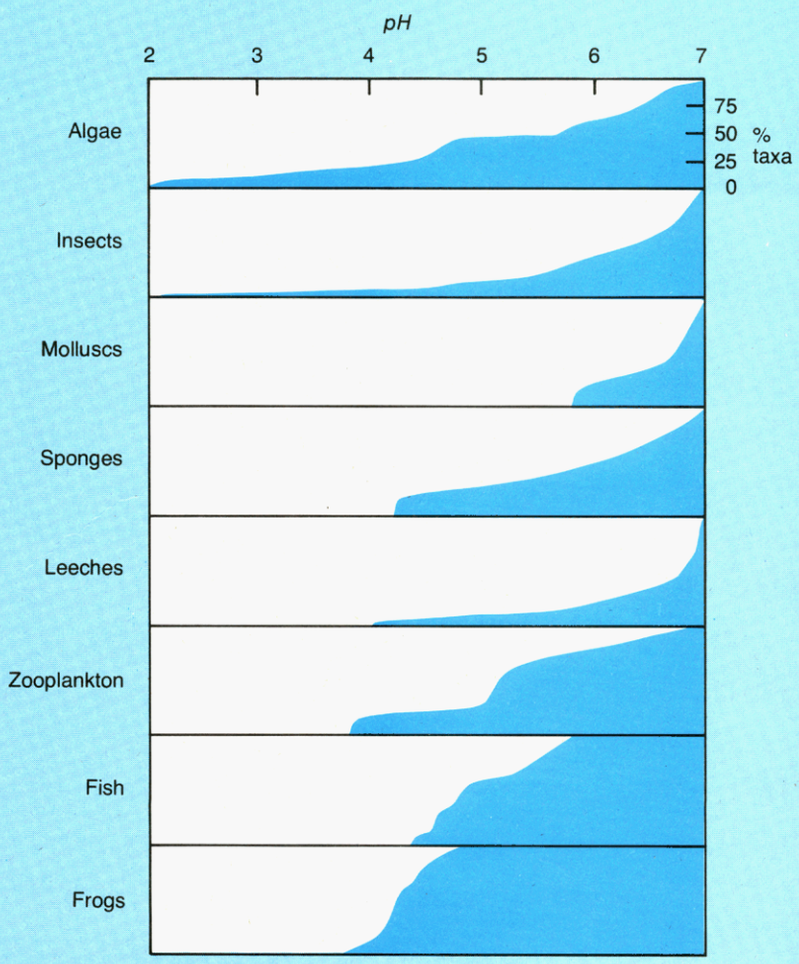
Acid deposition can have an effect on forests, crops, and soils, on groundwater supplies, and on man-made structures, but the effects on fish have been studied the most and are the most striking. When a lake is subjected to acid deposition, its acidity tends to follow a pattern that is similar to a titration curve (*ES&T*, November 1979, p. 1350); the pH declines slowly, usually imperceptibly, until the buffering capacity of the soil and water is depleted. Then, there can be a rather abrupt change in the acidity of the lake when the chemistry of the lake and its watershed components change appreciably. Consequently, consecutive measurements of lake acidity may give the impression that no very important changes are taking place. But when the acid-neutralizing minerals in the watershed are substantially depleted, there is a downward shift in pH accompanied by an increase in dissolved metals.

At first it was thought that acid alone was killing the fish—waters that are very highly acidic will, of course, kill fish—but it appears that aluminum dissolved from the soil by acid precipitation is responsible for mass mortalities. When strong acids come in contact with the soil, they react rapidly with aluminum compounds (usually $Al(OH)_3$) to release aluminum ions into the water.

A slower second reaction takes place between the aluminum ions and carbonate minerals in the soil such as limestone. If the buffering capacity of the soil is high enough and the water stays in the soil long enough, bases in the soil react with the aluminum and it does not pass into the lakes and streams. When these conditions are not met, aluminum goes into the lakes. Aluminum ions irritate fishes' gills and cause the gills to produce a protective mucus. This initiates a process that physically erodes the gill filament until the fish suffocate.

Acid lakes may appear to be "dead," but according to George Hendrey of Brookhaven National Laboratory, they are actually full of life, a strange limited life that is out of balance. Most or all fish species are missing and many

As the pH of a lake goes down, the diversity of aquatic life is reduced until very few species survive[a]



[a]Relative number of taxa of the major taxonomic groups as a function of pH

Source: J.M. Eilers and R.G. Berg, "Sensitivity of aquatic organisms to acidic environments," EPA report draft, Environmental Research Laboratory–Duluth, Minn., 1981

of the species of zooplankton that feed on algae are also missing, but the water is often very clear and beautiful and filamentous algae and fungi grow proliferously on the bottom of the lake. Gary Glass observed that, "As surface water quality is altered by continuous inputs of acid . . . the diversity of aquatic life is reduced until very few species survive."

The snowmelt of an early spring often has a deadly impact on fish because it very quickly releases all the acids that have accumulated over the winter at a time when the fry—the most vulnerable stage for fish—have just hatched. Not only are the acids released, they are concentrated in the first fraction of melted snow; the recrystallization of the fallen snow in combination with the freezing point depression phenomenon cause the most acidic snow crystals to melt first, releasing 50–80% of the pollutants in the first 30% of the snowmelt.

Acid rain and other wildlife

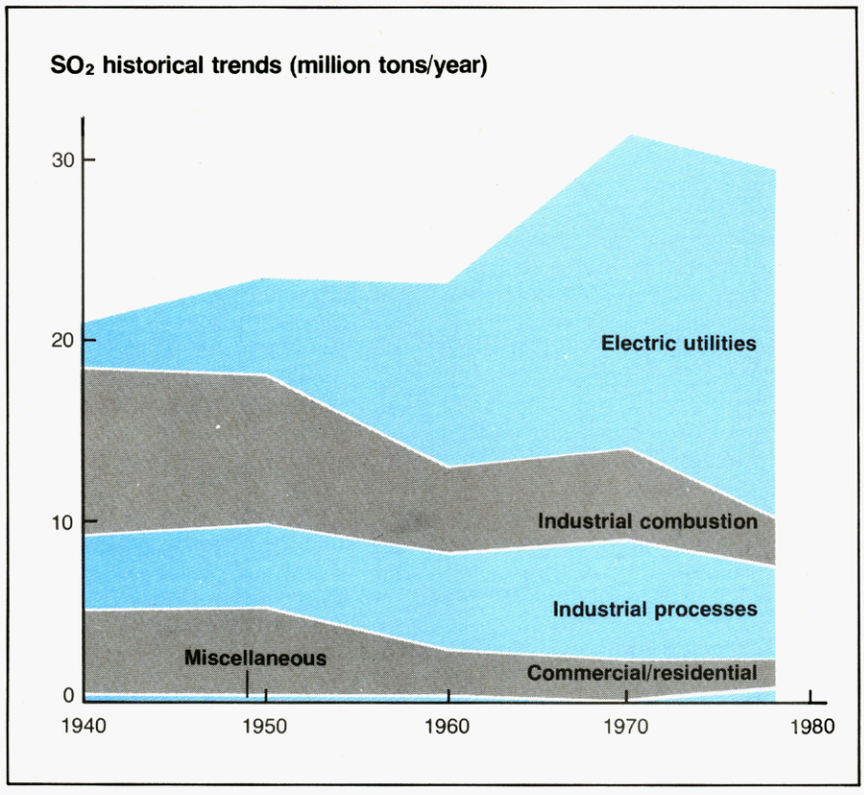
Amphibians, which breed in temporary ponds that collect drainage from a very limited area and have an acid content that is usually higher than in nearby lakes, are also extremely sensitive to acidification. At the symposium, Margaret Tome of Virginia Polytechnic Institute reported that a pH of 4 causes a 50% mortality in most amphibians. Again, the concentration of dissolved aluminum may be a more important factor than acidity per se. Since many birds and mammals depend heavily on frogs, toads, and salamanders for food, losses in amphibians may have far-reaching effects on both aquatic and terrestrial ecosystems. The same thing can be said of reductions in fish life. Several species of birds, such as the loon, will be endangered if a great number of lakes lose their fish.

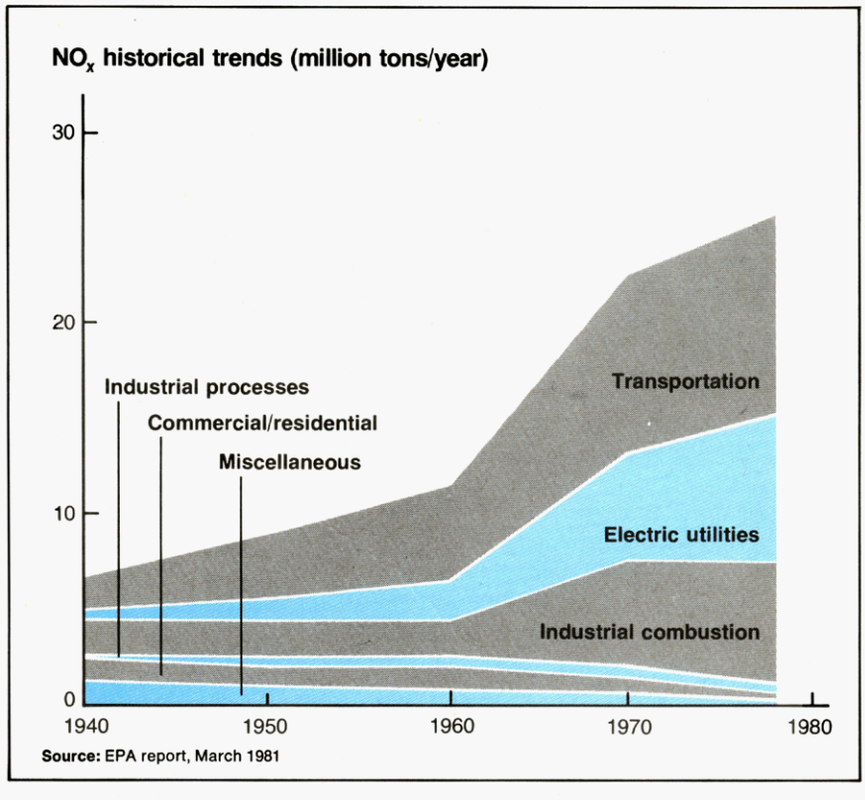
Other impacts

The effects of acid precipitation on plants and soil are not as well documented as the effects on fish. Much research remains to be completed in this area. Acid rain actually *helps* some cultivated crops—those that thrive in an acid soil. However, most of the sensitive regions of North America are not cultivated regions, but areas with thin soils where forests are the only possible crop.

In general, acid rain affects the soil by causing an increased rate of leaching of major elements and trace metals. Preliminary research results suggest that aluminum ions mobilized by acid rain kill some of the coniferous tree's feeder roots and as a result impair the tree's ability to take up an adequate amount of water and nutrients. Acid precipitation can also retard the decay of leaves and needles and thus the return of essential nutrients to the soil. Forest soils are especially endangered because they often have a low pH and a minimal nutrient status to begin with. Therefore, a further loss of nutrients is significant, even if small in an absolute sense. Since forest areas are not generally fertilized, it is quite impractical, if not impossible, to repair damage caused by acid rain.

Acid precipitation also corrodes marble, metal, stonework, and paint. The Europeans are especially concerned about acid-induced deterioration of historical buildings and monuments. It is nearly impossible to dis-





tinguish between damage caused by acid deposition and deterioration resulting from SO_2 or other pollutants. Studies in the past have shown that air pollutants collectively cause several billion dollars worth of damage annually in the U.S.

Of particular concern for human health is the acid-rain leaching of certain elements from the soil into drinking water supplies. Water with a low pH may also dissolve copper from pipes and the lead solder that is used to join the pipes. Gary Glass pointed out that, even in areas not considered sensitive, acid rain may cause a problem by adding sulfate and dissolved solids to surface water and increasing its salinity. This phenomenon may become important in parts of the West where surface and groundwater are becoming increasingly saline.

Conflicting research

The complicated nature of acid rain (*ES&T*, June 1981, p. 623) has given rise to the opinion that because some research results seem to be inconsistent, we cannot establish a definite cause-and-effect relationship between increasing emissions and the acidity of lakes and streams. One reason for conflicting results is that from the 1930s through the 1950s, pH measurements were not made directly and reproducibly. Chemicals were added to a water sample to produce a color indicator of acidity and alkalinity, and that process altered the variables being measured. Consequently, one set of data may seem to contradict another when actually they agree within their limits of error.

Because SO_2 emissions have decreased about 5% in the U.S. in the past five years, some people ask why the acid-rain problem seems to be getting progressively worse. Part of the answer is that a decline in national SO_2 emissions has been more than matched by an increase in the NO_x emissions. Another consideration is that watersheds which have already lost a great deal of their buffering capacity are still subject to much higher than normal inputs of acid. Acid has a cumulative effect on soils; unless limed, soils do not readily regain their buffering capacity and, as a result, acid inputs could cause a greater effect on lakes and streams than these inputs formerly had.

There is much we do not know about acid precipitation; many areas of investigation are unexplored or incomplete. For example, we do not know exactly how much the emissions of SO_2 and NO_x will have to be reduced in order to prevent further damage to the lakes. But when all the acid-rain research carried on in Europe, Canada, and the U.S. is put together, it comprises a large body of evidence that indicates that acid deposition is a serious and growing problem caused by continuing SO_2 and NO_x emissions from industrialized regions.

Control strategies

Because coal-burning power plants produce about two-thirds of the SO_2 emissions in the U.S., potential emission control strategies for SO_2 have been aimed primarily at these utilities. Aside from the very substantial reductions that could be made by conservation, there are several ways by which SO_2 emissions can be decreased. Coal can be washed prior to burning; low-sulfur coal can be substituted for high-sulfur coal; scrubbers can be installed on the power plants; plants that have low emissions can be used first, even if they are somewhat more expensive to operate; and the installations that pollute most can have their operations restricted to periods of peak demand.

There is a vast difference between the amounts of sulfur emitted by individual power plants. Older plants without scrubbers emit on the average more than 70 lb of SO_2 for every ton of coal they burn. New plants, which under present legislation must comply with New-Source Performance Standards, emit an average 12 lb of SO_2 for every ton of coal.

Many arguments are advanced to say that we know how to reduce SO_2 emissions, but we can't do it because it's too expensive. It *is* expensive. Scrubbers cost millions of dollars. But in a relative sense, reducing emissions is not very expensive.

A joint Department of Energy/EPA study found that eliminating the first 6 million tons of the 17.5 million tons of SO_2 produced yearly by power plants would increase the national utility bill 1.5–2%. In some states, the increase would be 10–20%, but these are the midwestern states, which now have relatively cheap electricity. To reduce SO_2 emissions by about half in the utility sector, i.e., to achieve a reduction of 8 million tons, would cost another $1.5 billion out of a total yearly electric bill of $100–150 billion.

Methods of controlling NO_x emissions are not as well developed. Catalytic converters on automobiles reduce the amount of NO_x produced by about three-quarters, and a low NO_x burner being developed for industrial boilers will decrease emissions by 80%.

A new method of coal burning being developed uses a mixture of coal and limestone and reduces both sulfur and nitrogen oxide emissions. This technology is only three to five years away from being available for both new and old coal-burning power plants.

Where are we headed?

The Clean Air Act now in effect contains no provisions that are designed specifically to control acid rain. Nor do the Reagan administration's proposals for revisions to the Clean Air Act address the problem of acid rain directly, except to recognize the importance of a strong research program. Many of the administration's proposals, if put into effect, would encourage increased rather than decreased SO_2 and NO_x emissions. Even though most new cars have already met the 1981 requirements, the Reagan plan would relax the NO_x emission standards for automobiles so that twice the emissions permitted under the 1981 requirements would be allowed. Elimination of the mandatory inspection and maintenance programs by the states is also being considered by Congress.

The situation with regard to SO_2 emissions is more problematical. The administration has proposed a relaxation of the emission controls required for new power plants. The results of that would make it more difficult to deal with the acid-rain problem in the future, but the overriding consideration is how much control should be required of existing plants. According to one EPA official, "The prognosis for SO_2 emission reductions in the future is not good, because it is clear that the administration is not prepared to continue pressing the utility industry to reduce further their use of high-sulfur coal."

Because so much of Canada is sensitive to acid rain and a large part of the Canadian economy depends on tourism and the forest and fishing industries, Canada is very concerned about acid rain and the direction in which the U.S. policies are moving. As an indication of how serious Canada considers the problem, Ontario has unilaterally ordered a substantial reduction of their SO_2 emissions, even though we send Canada several times more SO_2 than they send us. Environment Minister John Roberts said recently in regard to the administration's proposals for the Clean Air Act, "I am disappointed that the only reference to acid rain was in the context of research. I have on many occasions made the point that, while we need more research, we need reductions in acid-causing emissions urgently."

—Bette Hileman

Protecting Virginia's waterways

Several years after the Kepone incident, a National Wildlife Federation study suggested a number of strategies against toxic pollutants

What is the present status of Kepone and other toxic and hazardous chemical pollutants of the James River from Richmond, Va., to the Chesapeake Bay? Can a system for setting regulatory priorities be developed and applied to manage toxic substances and to avoid "Kepone-type" incidents in the future? Could the knowledge and regulatory strategies growing out of the Kepone episode and other toxic substance management needs for Virginia waterways be "extrapolated" to other water bodies nationwide?

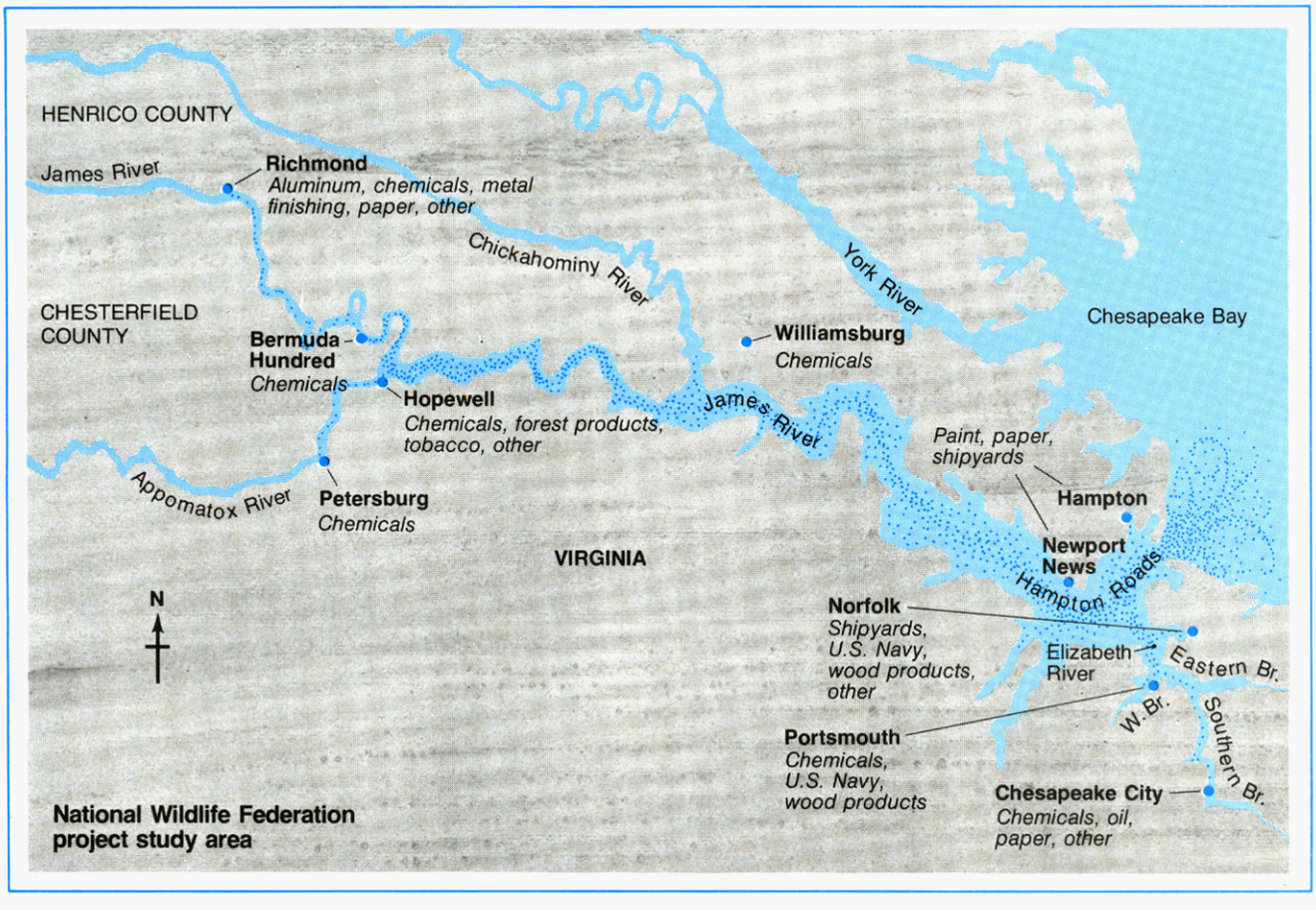
To answer these questions, and related ones, the Virginia Environmental Endowment engaged the National Wildlife Federation (Washington, D.C.) to study the matter in detail. The federation project, begun in 1980, resulted in "Pollution and its Control on the James River from Richmond to the Bay," a report submitted to the endowment and released in late July.

The endowment's concern is understandable, because federal, industrial, and municipal facilities along the James, and at its mouth, may be contributing substantial amounts of hazardous organic and inorganic chemical pollutants. Of particular concern are the industrialized areas of Henrico and Chesterfield Counties and of Richmond, Hopewell, Hampton, Newport News, and Norfolk.

The endowment was founded in Richmond, Va., in 1977. Its funds are used for environmental projects "of benefit to the people of Virginia," explained its executive director, Gerald McCarthy (*ES&T*, January 1979, p. 30); special emphasis is given to toxic substance and hazardous waste abatement. The endowment's first funding of $8 million was in lieu of part of a $13-million fine imposed by U.S. District Court Judge Robert Merhige, Jr. (Richmond) on Allied Chemical Co. as part of the "fallout" from the James River Kepone debacle of the mid- to late 1970s.

Toxic wastewater sources

If future Kepone-like episodes are to be prevented, a first step is to learn what is being discharged directly or through publicly owned treatment



0013-936X/81/0915-1125$01.25/0

works (POTWs). According to the federation study, the most heavily discharged materials along the middle and lower James River are oils and greases, caprolactam, and glycolates, originating from indirect dischargers (through POTWs) and the U.S. Navy. The study covered 66 industrial facilities discharging into the James River through POTWs (as well as the POTWs themselves), 36 direct-discharging industrial plants, and four Navy installations. It identified 95 individual toxic chemicals. Of these, more than two-thirds showed up in National Pollutant Discharge Elimination System (NPDES) records of only one facility. According to the federation, this situation reflects "either a localized release of these chemicals into the environment [by wastewater dischargers], spotty and incomplete reporting of discharge contents, or both."

The federation recommended that the Virginia State Water Control Board carefully screen all new NPDES applications for completeness—that all required concentration, quantity, and flow information is provided. Existing permittees should have their applications reexamined—especially "highest-hazard and potentially hazardous dischargers," for which insufficient information existed to permit full evaluation. The same rigorous permit evaluation should extend to federal facilities in Virginia, the report said. Although this was not reflected in the files reviewed by the federation, the water board commented that it is already taking these steps.

In addition, the report advocated that the water board should insist that NPDES permit applicants disclose the presence and concentrations of toxic pollutants in their discharges, *whether or not* such pollutants are on EPA's "priority pollutant" list. Requirements for analyses of all toxic pollutants suspected to be present, because of the nature of a process or for some other reason, were called for.

Bottom sediment

Concern was expressed that in waterways such as the James River, bottom sediments can receive and hold contaminants, especially fat-soluble, persistent ones, such as certain organometallics, Kepone, and PCBs. Also, many organohalogens may be prone to high degrees of bioconcentration.

By now, much of the Kepone-contaminated sediments deposited by the river have been buried under several centimeters of "diluted" sediments

The "Cairns matrix"

With respect to the ranking toxic pollutants and their dischargers, the report recommended that the water board and, eventually, EPA consider applying the "Cairns matrix" or a comparable methodology. Named after its developer, John Cairns of Virginia Polytechnic Institute and State University (Blacksburg), this matrix ranks chemicals on a scale of 1–12. The highest priority is denoted by "1." Priority is keyed to high, medium, or low biological impact; wide or localized distribution in the environment; and high or low rate of release into the environment.

While it is probably impossible to remove *all* attributes of qualitativeness and subjective judgment from water pollutant hazard evaluations, the "Cairns matrix" aims to provide as much quantification and objectivity as possible for such assessments. Still, to rank a pollutant's hazard potential, the federation, using the matrix, had to assign certain "cutoff points"; some may say that these points are arbitrary.

Thus, the federation made the "rule" that if a pollutant was identified in a direct or indirect industrial discharge one to four times, it was "localized." If it showed up five or more times, it was "widespread." Likewise, if the total quantity of a pollutant discharged was less than 500 g/d, a "low release" classification was assigned, while a 500-g/d or greater discharge led to a "high release" classification.

Biological impact ("high," "medium," "low") was categorized on the basis of relative toxicity, taken from EPA's updated "Water Quality Criteria" (1980). These criteria, in turn, are based on measured toxicity, environmental persistence, and several other properties. Additional factors governing biological impact classifications are bioaccumulation potential and proximity to shellfish beds and public drinking water supplies. For the purposes of the report, a "high" relative toxicity means that a pollutant at a given concentration in water would have to be diluted by a factor of 100 or more ("low" meaning a factor of less than 100) to meet applicable water quality criteria. As for bioaccumulation or bioconcentration, "low" would be a factor of less than 100 and "high" would be 100 or more, based on octanol–water partition coefficients or empirical data.

The "Cairns matrix"

Chemical dispersal	Biological impact [a] High (1)	Medium (2)	Low (3)
Widespread			
High release (1)	1	2	3
Low release (2)	2	4	6
Localized			
High release (3)	3	6	9
Low release (4)	4	8	12

[a] Low number indicates high testing priority.

Note: Cairns explained to *ES&T* that classification numbers not appearing in the matrix (5, 7, 10, 11) are arrived at with a certain amount of interpolation and subjective judgment.

Pollutants entering the James River

Pollutant	Hazard potential [a]	Pollutant	Hazard potential [a]
Cadmium	1	Zinc	1
Chromium	1	Copper	2
Lead	1	Thallium	2
Mercury	1	Ethylbenzene	3
Nickel	1	Acrylonitrile	4
PAH [b]	1	Aldrin	4
PCB	1	Beryllium	4
Pentachlorophenol	1	Linear alkyl sulfonates from	12
Phthalate esters	1	pilot plant operations [c]	

[a] Hazard potential values from "Cairns matrix" assigned by National Wildlife Federation.
[b] Polynuclear aromatic hydrocarbons represent 0.5% of oil/grease fraction.
[c] Not necessarily entering James River, but given by Cairns as an example of a pollutant with the lowest overall hazard potential rating.

Source: National Wildlife Federation and John Cairns

deposited by the river since 1976. But the report warns that a hurricane or dredging could stir up the bottom, reexpose and redistribute these sediments, and even carry them to the Chesapeake Bay.

The study called for "innovative" dredging techniques to minimize or obviate disturbances of Kepone-containing sediment. Any contaminated dredged material should be placed in adequately protected upland containment sites. (The Virginia water board argued that upland containment could spread the problem, rather than confine it.) Also, mitigation techniques such as activated-carbon elutriate treatment, ultraviolet/ozone processing, and fixation should be evaluated in response to any movement of Kepone in the James River, the report suggested.

Identification and ranking of pollutants and their hazards is one way to establish "sediment quality criteria" on a waterway-by-waterway basis, the federation proposed. These criteria could apply to all pollutants of high hazard potential in a waterway, with highest priority assigned to those segments serving as public water supply sources or shellfish beds. Ambient stream monitoring programs should be adjusted to concentrate on high-hazard pollutants, and their presence in water, sediments, and biota. The fereration said that such an effort is needed not only in Virginia, but nationwide, perhaps at the initiative of EPA and the U.S. Army Corps of Engineers.

This recommendation may have been very timely. McCarthy noted that the latest James River fish samples for June and July showed that once again Kepone levels are above the Food and Drug Administration's 0.3-ppm "action level." He said that a recent drought in the area might have been partially to blame.

Other issues

Under the heading of general issues of regulation and coordination, the federation study came up with 99 findings, 45 conclusions, and 57 recommendations. Among the more salient points was a recommendation that the state water board incorporate selected screening for carcino-, muta-, and teratogenicity into its existing ambient and biological monitoring program, especially where human water or food—particularly shellfish—supplies are concerned.

Another recommendation calls for the water board not only to ensure that chlorine levels in water do not exceed 0.05 ppm, but to incorporate a margin of safety. Also recommended were water quality standards for chlorine and chloramines in shellfish-growing areas, as well as guidelines for metals, such as cadmium and lead. Moreover, the report suggested that the water board, the Marine Resources Commission, and the Virginia Institute of Marine Sciences "identify effective, nonhalogenated wastewater treatment methods and disinfectants."

A high research priority for "more sophisticated chemical residue detection methods" for water and living tissues was called for, with special emphasis on PAHs and organohalogen components in tissue. The report also recommended developing a better understanding of depuration—the mechanism by which living organisms (especially molluscs, in this case), are purged of contaminants—and the time necessary for such purging.

Implementation

Now that it has received the federation's report, how does the Virginia Environmental Endowment hope to see it implemented? After all, the federation and the endowment cannot, themselves, promulgate or enforce regulations; moreover, the endowment, with its total staff of three, is mainly in the business of awarding and administering environmental grants.

The endowment's McCarthy told *ES&T* that his group sent copies of the report to responsible people in Virginia state regulatory agencies and that the study received an enthusiastic reception from many working-level scientists, technicians, and enforcement personnel in those agencies. Copies are also being circulated among citizens' groups and others who can help to exert pressure for increased enforcement of existing regulations and for implementation of the report's recommendations, especially those concerned with the highest-hazard pollutants. The federation has acknowledged that Virginia's water program is "sound and effective."

The water board and the State Health Department observed that the report "contains some useful recommendations." Nonetheless, those agencies and others have raised certain arguments. For instance, the water board says that with respect to NPDES permittees, it already "does the function" set forth in several of the federation recommendations. Other differences of opinion center on the lack of necessary equipment and expertise, the expense involved in implementing many of the recommendations, and the belief that impacts of certain chemicals do not present the hazards the federation claims they do.

There are several other disagreements between the federation report's findings, conclusions, and recommendations, and those of the various cognizant state agencies. It remains to be seen to what extent Virginia will implement those recommendations, at least within the state's technical and financial limitations, and what ultimate nationwide applicability the report will have. —Julian Josephson

Project accomplishments

Managed by Kenneth Kamlet and coordinated by Senta Rogers, the federation project:

- evaluated the adequacy and efficiency of federal, state, and local programs to safeguard health and the environment from the discharge of toxic wastewaters into surface waters in the study area
- analyzed relevant federal and state health and environmental laws/regulations to determine whether they are adequate to control the release of hazardous wastewater contaminants
- evaluated Virginia's overall management system for regulating and controlling toxic substances, with special emphasis on the ability of state agencies to coordinate their activities
- evaluated the extent to which the U.S. Army Corps of Engineers, EPA, and Virginia consider the hazard potential of bottom sediments at and below toxic wastewater discharges when making dredging and management decisions
- obtained limited field verification of case-study findings by taking samples and doing analyses in cooperation with research and regulatory institutions
- gave credit to the system where it works and offered constructive suggestions for improvement where it doesn't
- suggested specific follow-up measures to implement the project's recommendations and ensured that those recommendations were available to those involved with implementation

To avoid future duplication of effort, the federation compiled an annotated bibliography for those who wish to verify or pursue the project's findings and recommendations. The bibliography and a summary of the full report are available from the National Wildlife Federation, 1412 16th St., N.W., Washington, D.C. 20036.