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Acid Deposition: Legal and Political Controversies

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ACID DEPOSITION:
LEGAL AND POLITICAL CONTROVERSIES

BY

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INTRODUCTION

Acid rain is more accurately referred to as acid deposition since acidity is deposited in both the wet and dry form. Acid rain results from the conversion of sulfur and nitrogen gases to sulfates and nitrates, respectively. In the United States, sulfur compounds are responsible for about two-thirds of the acidity in precipitation; nitrogen compounds, one-third (1). Approximately ninety percent of the total sulfur compounds emitted are attributed to electric utilities and industrial fuel combustion sources. In Canada, copper and nickel smelters account for the majority of SO_2 emissions, with most point sources located in eastern Canada (2).

A decade ago the terms "acid precipitation" and "acid rain" were used almost exclusively by specialists in the fields of ecology and atmospheric science. Today, these terms have become worrisome household words in many countries. The awareness of environmental effects from precipitation dates as far back as 1661 at which time several English researchers noted that industrial emissions affected the health of people and plants, and that there was significant transboundary exchange between France and England (3).

One of the first researchers to describe the acid rain phenomenon was an English chemist, Robert Angus Smith. In 1852, Smith published a report on the chemistry of rain in and around the city of Manchester, England. Smith found changes in precipitation chemistry as one moves from the middle of a city to the surrounding countryside. Three compositions of air were identified; those with carbonate of ammonia in the fields at some distance, those with sulfate of ammonia in the suburbs, and those with sulfuric acid, or acid sulfate, in the town. It was not until 20 years later (1872) that Smith coined the phrase "acid rain" in his book Acid Rain: The Beginning of a Chemical Climatology (4). Although not recognized at the time, this book enunciated many of the basic ideas still accepted today.

Serious concern over a potential acid rain problem came in the later 1950's and early 1960's. Measurements by Scandinavian scientists indicated a connection between acid rain, the increasing acidity of lakes and streams, and the disappearance of fish. In 1968, the Swedish scientist Svente Oden summarized evidence that the acidity in Sweden's precipitation was increasing and presented evidence from an analysis of airmass trajectories that much of the acid rain in Scandinavian was produced by sulfur dioxide emissions in England and Central Europe (5).

That same year, Norway initiated an eight year study of the effect of acid rain on forests and aquatic resources.

At its conclusion, Norwegian scientists reported that Norway's seven southern rivers were 30 times more acidic than northern rivers (pH 5.12 vs pH 6.57, average) (6). Between 1966-1976, the acidity of these seven rivers doubled, and the salmon catch decreased to near zero in all of the lakes (7). A survey of 5,000 lakes in southern Norway found that the trout population had become extinct in 22% of the low-altitude lakes (below 600 ft) and in 68% of the high-altitude lake (above 2,6200 ft).

At the same time, awareness of the acid rain problem was growing in the United States and Canada. In the mid-1950's, the ecologist Eville Gorham documented the effects of acid precipitation on Canadian lakes, vegetation and soils. Gorham's concern was the effects of pollution from metal smelters, especially the giant nickel smelter in Sudbury, Ontario. This smelter is the largest point source of sulfur dioxide in the northern hemisphere.

United States scientists were beginning to focus on the effects acid rain had on lakes in the Adirondack Mountains. A typical example of acidification of a lake ecosystem is Lake Colden, a 38 acre lake at elevation 2,673 ft, located in Essex County, New York. Anglers' records from the 1930's indicated that at that time there was excellent fishing. By 1950, anglers were registering complaints despite current stocking of the lake. In 1965, the pH was 5.0, and by 1970 the lake had become 2-3 times more acidic. Surveys of the lake in 1970 and 1973 found no trout and it was decided to terminate stocking (8). This sequence of events has been a very common occurrence throughout lakes in northeastern United States.

A comprehensive study of 1,000 Adirondack lakes and ending in 1979 ponds showed that approximately 25% of the lakes had acidified and could no longer support trout and other game fish (9). Acidification of lakes and streams has also occurred in areas of New England, New York, New Jersey, Pennsylvania, West Virginia, and North Carolina (10). Fish kills have been reported as far south as Great Smokey Mountains in Tennessee, when spring melting of snow sends a pulse of acid that has accumulated in the snow over the winter into lakes and streams (11). A growing awareness of the impacts of acid precipitation on fish populations and the potential effects on forests led the United States Forest Service to sponsor the First International Symposium on Acid Precipitation and the Forest Ecosystem (in Ohio, May 1975). In July 1975, Ellis B. Cowling, from the School of Forest Resources, North Carolina State University, testified before the Subcommittee on the Environment and the Atmosphere, Committee on Science and Technology, that research on acid rain in the United States was inadequate for the seriousness of the problem. He observed that coordinated programs of research on the ecological effects as well as a suitable monitoring network were lacking (12).

This testimony initiated the formation of the National Atmospheric Deposition Program (NADP) which involved numerous scientists in various institutions and agencies throughout the United States.

During the early 1980's, an event in the Federal Republic of Germany highlighted the potentially devastating effects of acid rain to forests. It was discovered that since 1981 ever increasing areas of the Black Forest and the forests of Bavaria were being affected by acid rain (from 8% in 1982, to 34% in 1983, to 54% as of the latest estimate)(13). Between 1982-83, Germany's policy on acid deposition turned around 180 degrees, from a country that was opposed to increased controls on emissions of acid gases to a country that presently has the most stringent controls on both stationary and mobile sources of emissions.

As more is learned about acid rain, the importance of compiling a detailed historic data record from which to assess changes caused by anthropogenic pollutants on the natural environment becomes more important. Southern Greenland provides an optimal site from which a record of sulfate and nitrate emissions from North America can be deduced. Results from an ice-core that covers the years 1869-1984 revealed that mean sulfate concentrations remained fairly constant (approximately 26ug/kg per 30years) between 1870 and 1960. Over the next 24 years (1960-1984) mean sulfate concentrations almost tripled, increasing 74ug/kg.

Mean nitrate concentrations for the same time peraiods increased at approximately the same rate (14). These increases are well correlated with emission records from other ice cores during the latter time periods (15).

PAST AND FUTURE EMISSIONS

In 1980, manmade sources in the United States emitted approximately 26 million tons of sulfur dioxide and 21 million tons nitrogen oxides. Of this, the 31 states east of, or bordering the Mississippi River accounted for 22 million tons of sulfur dioxide and 14 million tons of nitrogen oxides (16). Within the United States, the major sources of sulfur dioxide emissions, approximately 90-95% of the total, are electric generating utilities, industrial boilers, and industrial processes. Utilities, mobile sources and industry produce greater than 95% of the nations manmade nitrogen oxide emissions.

A reasonably complete data set exists for emissions for sulfur dioxide and nitrogen oxides within the United States over the last three decades. Emissions of these between 1900 and 1950 must be inferred using available historical records. Table 1(17) presents 1980 emission values for sulfur dioxide, nitrogen oxide and hydrocarbons for each of the 50 states (18). In comparison, Table 2 (19) shows estimated total United States and Eastern 31-state emissions of sulfur dioxide, nitrogen oxide and total hydrocarbon emissions for several years between 1940-1980. Between 1940-1970, sulfur dioxide emissions increased by 50%, from 19 million to 30 million tons per year. From 1970-1980, sulfur dioxide emissions showed a slight decline. Figure 1 (20) illustrates state level sulfur dioxide and nitrogen oxide emission estimates for 1950-1980.

Future emissions of both sulfur dioxide and nitrogen oxide will depend upon three factors:

1) future demands for energy, (energy for electrical generation, industrial fuel use and automobiles);

2) the type of energy to be used, (nuclear and hydroelectric power hopefully produce no emissions and natural gas produces fewer emissions); and

3) the rate at which existing pollution sources are replaced with newer lower emission sources which are more tightly controlled under the Clean Air Act.

Table 1 —1980 Total Emissions of Sulfur Dioxide, Nitrogen Oxides, and Hydrocarbons in the United States
(1,000 tons/year)

State	SO_2	NO_x	HC	State	SO_2	NO_x	HC
Alabama	760	450	530	Montana	160	120	160
Alaska	20	55	50	Nebraska	75	190	200
Arizona	900	260	250	Nevada	240	80	70
Arkansas	100	220	270	New Hampshire	90	60	100
California	445	1,220	2,550	New Jersey	280	400	810
Colorado	130	275	360	New Mexico	270	290	195
Connecticut	70	135	370	New York	950	680	1,250
Delaware	110	50	70	North Carolina	600	540	680
District of Columbia	15	20	35	North Dakota	100	120	70
Florida	1,100	650	880	Ohio	2,650	1,140	1,280
Georgia	840	490	580	Oklahoma	120	520	460
Hawaii	60	45	75	Oregon	60	200	330
Idaho	50	80	170	Pennsylvania	2,020	1,040	1,360
Illinois	1,470	1,000	1,200	Rhode Island	15	40	120
Indiana	2,000	770	700	South Carolina	330	200	550
Iowa	330	320	300	South Dakota	40	90	110
Kansas	220	440	350	Tennessee	1,100	520	580
Kentucky	1,120	530	430	Texas	1,270	2,540	3,400
Louisiana	300	930	790	Utah	70	190	160
Maine	100	60	120	Vermont	7	25	45
Maryland	340	250	370	Virginia	360	400	530
Massachusetts	340	250	600	Washington	270	290	500
Michigan	900	690	1,100	West Virginia	1,100	450	150
Minnesota	260	370	500	Wisconsin	640	420	530
Mississippi	280	280	330	Wyoming	180	260	110
Missouri	1,300	570	690	U.S. total	26,500	21,220	28,350

Table 2 -Historical Trends in Sulfur Dioxide, Nitrogen Oxides, and Hydrocarbon Emissions (millions of tons)

	Sulfur dioxide		Nitrogen oxides		Hydrocarbons
Year	National[a,b]	Eastern 31 States[b]	National[a,b]	Eastern 31 States[b]	National[a]
1940	19.1	—	7.2	—	15.3
1950	18.1-21.6	14.6	7.4-10.3	5.4	19.3
1955	17.7	14.3	8.5	6.4	—
1960	21.2-22.2	18.9	11.5-14.0	8.5	23.8
1965	26.7	22.8	14.2	10.4	—
1970	28.7-30.8	24.0	17.7-20.4	12.4	29.8
1975	27.3-28.2	23.4	19.3-21.6	13.3	25.1
1980	25.2-26.1	21.2	21.0-22.8	13.9	24.0-28.3[c]

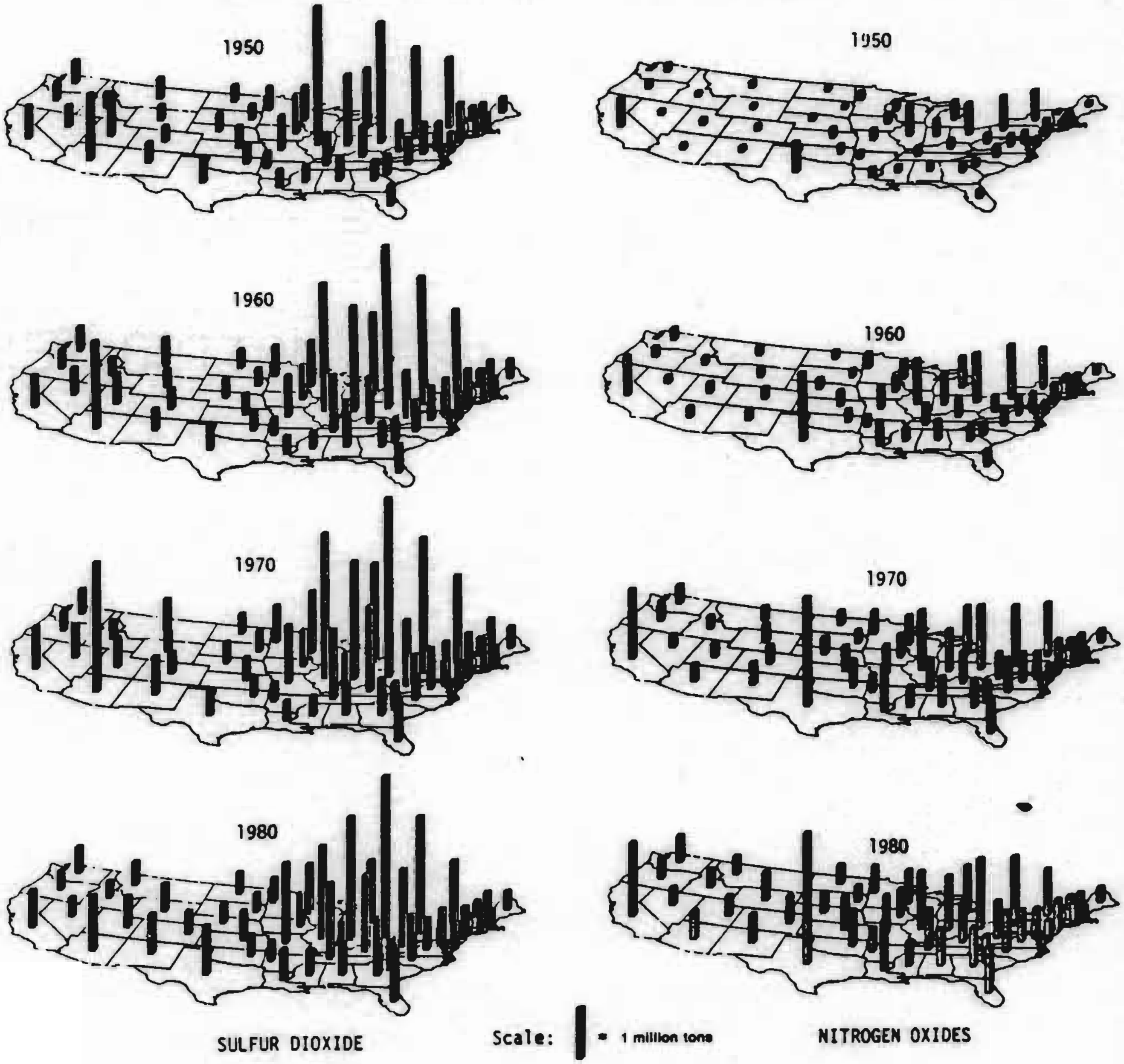
SOURCES: [a] *National Air Pollution Emission Estimates, 1940-1980*, U.S. Environmental Protection Agency, January 1982, EPA-450/4-82-001.

[b] "Historic Emissions of Sulfur and Nitrogen Oxides in the United States from 1900 to 1980," G. Gschwandtner, et al., 1980. Draft reports to EPA from Pacific Environmental Services, Inc.

[c] *Emissions, Costs and Engineering Assessment*, Work Group 3B, United States-Canada Memorandum of Intent on Transboundary Air Pollution, June 15, 1982.

Source, Acid rain and transported air Pollutants, Off. of Technol. Assess. Washington. D.C., OTA-O-204 (1984).

Figure 1 —SO_2 and NO_x Emissions From 1950 to 1980, By State



Source, Acid rain and transported air Pollutants, Off. of Technol. Assess. Washington. D.C., OTA-O-204 (1984).

Sulfur dioxide emissions for the United States as a whole are predicted to increase over 1980 levels by 10-25% by 2000, and again by 20-30% by 2010. The largest rate increase will be in the industrial sector (25-40% by 2000). Similarly, within the 31 Eastern states the fastest growth will be within the industrial sector. By 2000, total sulfur dioxide emissions within the eastern 31 states are projected to increase by 10-30%, while the industrial sector alone will increase between 50-90% (21).

Presently, automotive emissions are the single largest nitrogen oxide-producing sector, however, by 2010 emissions from utilities are expected to be the single largest source of nitrogen oxides. Nitrogen oxide emissions for the United States are expected to increase by 25% over 1980 levels by 2000; by 2010, emissions are forecasted to increase by 50-55%. Utilities will account for most of this increase (approximately 60-75%)(22).

In the eastern half of the United States, factors affecting forecasts of sulfur dioxide emissions are; 1) demand for electricity (range of 2.0-3.0% per year), and 2) retirement age of existing plants (range of 40-60 years). Other factors include reliance on nonfossil fuel sources, emissions from newly built electric generators and industrial plants, and reductions required to comply with government regulations.

CHEMISTRY: FORMATION OF ACIDITY

The atmosphere is a mixture of numerous chemicals. Some enter the atmosphere naturally, some are of anthropogenic origin, and some are both. Interactions between these chemicals vary under different conditions.

Acid deposition is produced by alteration of certain air pollutants. When fuels such as coal and oil are burned, sulfur and nitrogen in the fuel are released into the air and combine with oxygen to form sulfur and nitrogen oxides. The sulfur oxides are chiefly sulfur dioxide, SO_2, with lesser amounts of sulfur trioxide; and the nitrogen oxides are a mixture of nitric oxide, NO, and nitrogen dioxide, NO_2. The nitrogen oxides are abbreviated (NO_x)(where x stands for 1 or 2). In contact with air and water, SO_2 and NO_x are further oxidized to form acid sulfate and acid nitrate. The chemical reaction is as follows.

$$SO_2 + 1/2\ O_2 + H_2O \dashrightarrow 2\ H^+ + SO_4^{2-}$$

$$NO + NO_2 + O_2 + H_2O \dashrightarrow 2H^+ + 2NO_3^-$$

These reactions take place spontaneously, and are driven by the stability of the end-products, sulfate (SO_4^{2-}), and nitrate (NO_3^-). The rate and alteration pathway for a given emission depends on: 1) the initial concentrations of all pollutants; and 2) a number of physical factors, such as wind speed, air turbulence, temperature, sunlight intensity, and rainfall frequency (23).

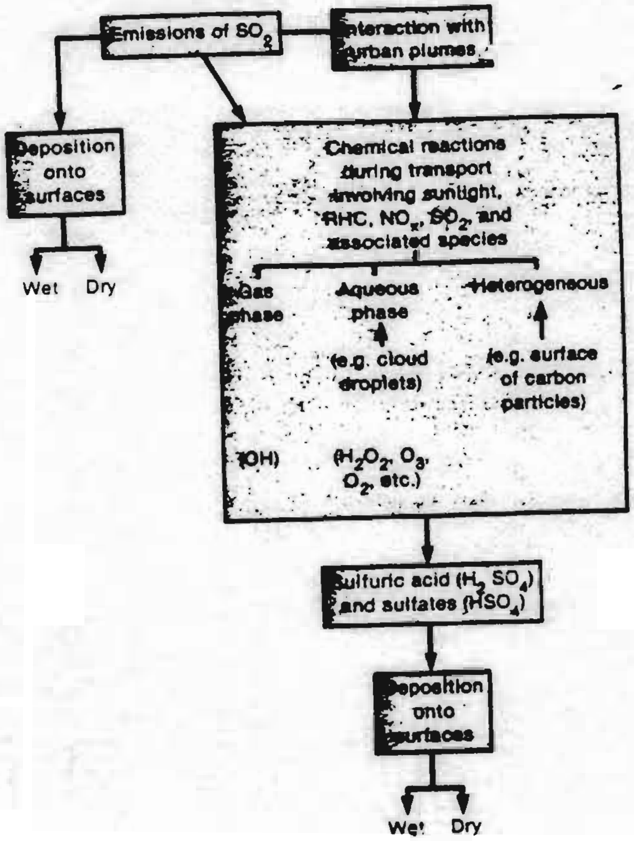
Two possible fates exist for sulfur and nitrogen pollutants: 1) oxidization to sulfuric and nitric acids (or sulfate and nitrates) followed by deposition at the earth's surface; or 2) deposition in their emitted form (unchanged). In the latter case, chemical oxidation on the earth's surface may cause the same net result as case 1 - i.e., acidification.

A schematic diagram of possible fates of emitted sulfur dioxide gas is given in Figure 2 (24).

DEPOSITION

As discussed above, to become acids sulfur dioxide and nitrogen oxide may be oxidized either 1) in the gas phase, 2) after absorption into water droplets, or 3) after dry deposition on the ground. These materials can be deposited

Figure 2 —Schematic Diagram of Possible Fates of Emitted Sulfur Dioxide Gas



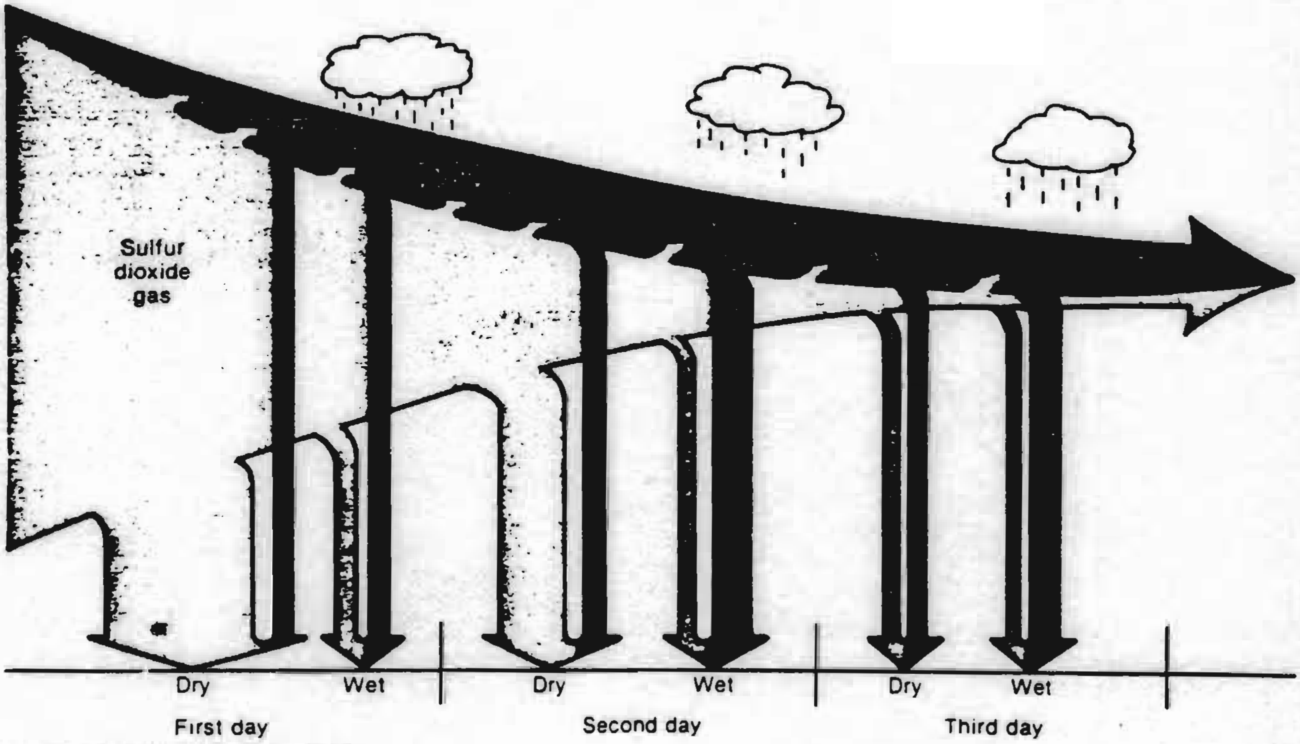
Source, Acid rain and transported air Pollutants, Off. of Technol. Assess. Washington. D.C., OTA-O-204 (1984).

unchanged as primary gaseous pollutants, or in a transformed state as secondary pollutants. Transformed pollutants can be deposited in wet form (rain, fog, snow), or dry form (particles settling out). The time these pollutants will remain in the atmosphere depends significantly on their chemical form. As an example, sulfur dioxide gas is dry-deposited at a faster rate than sulfate particles. If sulfur dioxide is rapidly changed to sulfate, a smaller fraction of emitted sulfur will be deposited locally, if no precipitation occurs.

Dry deposition occurs at a fairly constant rate over time, whereas wet deposition is more episodic, and the amount deposited with time varies considerably, even within one rainfall. In general, areas close to emission sources receive the majority of their pollution from steady dry deposition of sulfur dioxide. Areas that are remote from the source do not receive much in the form of dry deposition. In these areas, wet deposition accounts for most of the pollutant dose (Figure 3). Over most of Eastern United States, wet and dry contributions of sulfur compounds are estimated to be about equal.

Figure 3 —The Effects of Time and Distance on Conversion and Deposition of Sulfur Pollution

Sulfur can be deposited in both its emitted form, sulfur dioxide (lighter shading), and as sulfate, after being chemically transformed in the atmosphere (darker shading). Both compounds can be deposited in either dry or wet form. The relative amount of sulfur deposited in these forms varies with distance from emission sources. Dry deposition predominates in areas close to emission sources. Wet deposition is responsible for a larger percentage of pollutant load in areas distant from source regions.



SOURCE: Office of Technology Assessment.

Source, Acid rain and transported air Pollutants, Off. of Technol. Assess. Washington. D.C., OTA-O-204 (1984).

ECOLOGICAL EFFECTS

Acidic deposition poses a threat to ecosystems. In the soils and surface waters, damage to the ecosystem occurs when the types of minerals present cannot neutralize acidified rain, snow, and dry deposited materials. Susceptible soils and waters are said to have low "buffering capacity" because they cannot readily neutralize acids. Compounds, such as calcium and magnesium carbonates, when present in the soil, may be leached by acidic deposition and enter water bodies while acidity remains in the soil. When soil become highly acidic, exhausting their buffering capacity, similar leaching of other trace metals such as aluminum can occur. These leached metals will also cause damage to aquatic life in lakes and streams. Soils can retain sulfuric acid to varying degrees. In some cases, deposited sulfuric acid will not pass into lakes and streams until the "absorption capacity" of the soils is exceeded. Areas where the absorption capacity is very low are acid-sensitive regions. These are shown in Figure 4 (25). These areas include the mountainous regions of New York, New England, the Appalachian Mountain chain, including portions of Pennsylvania, West Virginia, Virginia, Kentucky and Tennessee, upper Michigan, Wisconsin and Minnesota, and the Pre-Cambrian Shield of Canada, including Ontario, Quebec and New Brunswick.

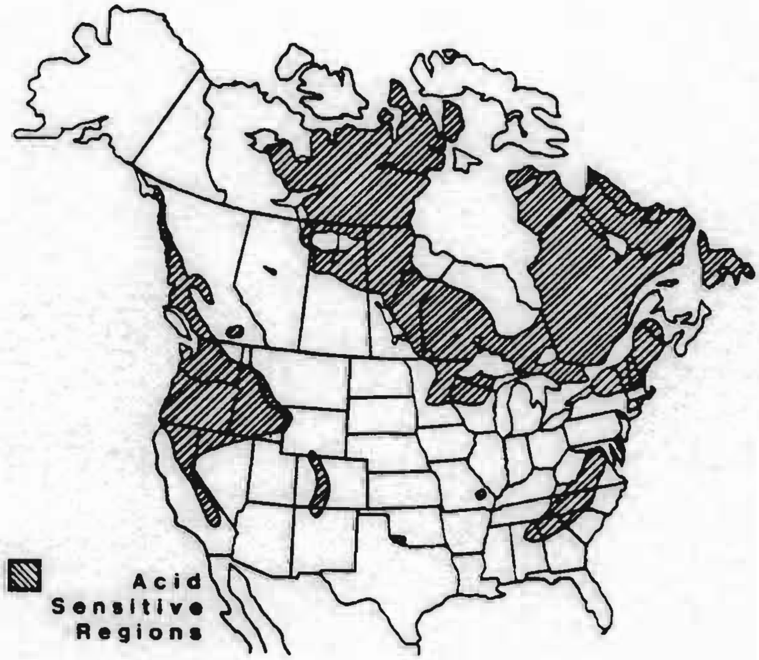


Figure 4 Acid-sensitive ecosystems in North America.

Source, Acid rain and transported air Pollutants, Off. of Technol. Assess. Washington. D.C., OTA-O-204 (1984).

EFFECTS OF ACID DEPOSTITION ON LAKE AND STREAMS

Under unaltered conditions, all lakes and streams have some acid neutralizing capacities. Like soils, waters also contain compounds such as carbonates, which neutralize entering acids. When acids enter lakes and streams, available neutralizing substances are consumed and remaining neutralizing substances are decreased. As water bodies become acidified, aquatic plants and animal populations may be altered.

Regional water quality surveys were used to estimate the percentage of lakes and streams in 14 regions (26) that can be considered sensitive to acid deposition. Results indicate that an estimated 9,400 out of 17,000 lakes and 60,000 out of 118,000 miles of streams are currently in danger of being significantly altered by acid precipitation (27)(Table 3). It has been estimated that, of the total number of lakes and streams in these 14 regions, 3,000 lakes and 23,000 miles of streams have already been altered by acidity. This comprises 18% of the lakes and 20% of streams(28).

Biological responses to acidification of freshwater environments depend not only on the pH level, but also upon concentrations of substances such as sulfate, calcium, aluminum and organic materials. Even when the acidity (pH) of two lakes are similar, existing fish populations may change in the same manner (29). This is because other

Table 3 —Total Estimated Lake and Stream Resources in the Acid-Sensitive Regions of the Eastern United States (see fig. B-1)

Region	Sensitive area (mi²)	Total lakes		Total streams (mi)	
		Number	Acres	1st order	2d order
1. Eastern Maine	26,398	1,425	582,825	9,714	3,485
2. Western New England	29,666	1,543	763,785	15,308	4,569
3. Adirondacks	14,066	1,139	231,217	5,289	3,024
4. East Pennsylvania/ South New England	20,947	1,320	118,800	8,400	2,556
5. West New York/Pennsylvania	25,051	376	16,920	7,114	1,678
6. Appalachian Plateau	16,190	13	29,510	7,350	2,299
7. Blue Ridge/Great Smoky Mountains	20,964	126	14,868	10,901	3,396
8. Coastal Plain	9,264	241	8,917	1,547	713
9. Lower Mississippi	13,075	170	56,610	5,374	1,255
10. Indiana/Kentucky	8,603	9	603	2,805	989
11. Central Wisconsin	12,141	583	187,726	2,683	728
12. Wisconsin/Michigan Highlands	19,229	5,307	801,357	5,037	1,737
13. Northeast Minnesota	10,560	1,637	473,093	1,637	475
14. Central Minnesota	18,870	3,170	323,340	4,831	2,529
Totals	245,024	17,059	3,609,571	87,990	29,433

Source, Acid rain and transported air Pollutants, Off. of Technol. Assess. Washington. D.C., OTA-O-204 (1984).

factors (metal concentrations, temperature, light, etc.) may interact differently, thus affecting fish populations differently.

Decreasing or complete loss of fish populations attributable to the effects of acid deposition has received an enormous amount of public attention. Indirectly, acid deposition may cause numerous changes in many forms of aquatic life, from single-celled algae to large aquatic plants to amphibians such as frogs and salamanders. Alterations in the lower end of the food web ultimately affect other animals such as fish, aquatic birds and mammals. In order for fish reproduction to take place even at a greatly reduced fecundity requires the water pH to be above 4.5. For a natural survival rate, water pH must be above 6.5 (30). Death of most fish species does not occur until pH levels are less than 4.5. Species tolerance varies, thus some species will disappear before others. Maximum fish kills occur in early spring when the first snow meltwater enters the lakes and streams. This produces an "acid shock" effect that is caused by accumulation of acids in snow over a whole winter. This first melt may be 5-10 times more acidic than average rainfall in the area.

A recent study indicated that acid rain may be threatening Atlantic salmon by interfering with their ability to find their home stream for spawning. This studie indicates that moderate levels of acidity in water can confuse a salmon's sense of smell, or the olfactory memory with which spawning salmon find their way up the right river and tributary to lay eggs at their place of birth. Hence acid rain, while not directly killing the salmon, may cause the fish to spawn in the wrong places, which often provide poorer conditions for development of eggs and young fish than the salmons' original stream (31).

Studies have shown that amphibian populations, such as frogs and salamanders, are extremely sensitive to changes in pH. Many of these species breed in early spring, the time when the lowest pHs occur due to melting of the winter snows. There is a direct correlation with low pH values and both death and embryo deformation in frogs and salamander populations (32).

Many invertebrate animals are also affected by acidification of waters. The shell bearing organisms and molting crustaceans are the most sensitive to lowered pH (33). No molluscs can exist in waters of pH lower than 6.0 and crustaceans rarely occur in waters of pH below 4.0. Aquatic insects sensitivity to pH varies enormously. When bug eating fish disappear, certain acid-resistant insects will thrive. Acid sensitive insects will disappear rapidly.

Single-celled algae (phytoplankton) are the building block of the food chain. As pH decreases, significant changes occur in the species and diversity of algae that predominate (34). Acid-tolerant algae proliferate as lakes and streams acidify and acid-sensitive algae die out. These acid-tolerant algae are not readily edible by zooplankton and other animals that link algae and smaller fish in the food chain (35).

Acidification is almost always accompanied by changes in the abundance and diversity of zooplankton which may reflect changes in food sources (algae), predators (fish), and/or water chemistry. With decreases in zooplankton diversity, density and average size, the available food source for fish and other animals is reduced

It has been suggested that larger aquatic plants may become covered by acid-tolerant algae populations, thereby lowering or halting the plants ability to receive sunlight (36).

EFFECTS OF ACID DEPOSITION ON TERRESTRIAL MATERIALS

One-third of the total land area of the United States is forested, two-thirds of that area (approximately 400 million acres) is commercial timberland. Two-thirds of this commercial timberland occurs in the 31 states east of the Mississippi, distributed equally between North and South.

Studies have shown that acid deposition onto forested areas can 1)damage leaves, roots, and microorganisms that live symbiotically with roots; 2) impair reproduction and growth of seedlings; 3) leach nutrients from soils; 4) dissolve metals in soils such as aluminum that are toxic to plants; and 5) lower the plants' resistance to other detrimental factors such as pollution, insects and pathogens.

Studies have shown that almost all forests in the eastern United States have been affected. For example, it has been estimated that in Vermont's Green Mountains, 50% of the red spruce have died and the number of seedlings has declined 50% since 1965 (37). Also documented is the decline in growth rate of evergreens in the Adirondacks (38), in New Jersey (39), and in Maine. Pine trees in the Great Smokey Mountains, Tennessee have virtually stopped growing during the past 20-25 years (40). During these years the regional sulfur dioxide emissions from fossil fuel combustion has increased some 200%. Numerous studies have found the decline in forest growth to be accompanied by increased concentrations of aluminum, cadmium, copper, zinc and other toxic metals in the tree growth rings. Metals may enter the tree through its roots after being dissolved from the soil by acidic deposition, and/or may be deposited directly onto leaves. A similar scenario takes place in the forests of the Midwest (41).

Soils are also affected by acid deposition. Acid deposition can cause loss of essential compounds such as calcium and magnesium; can cause the release of toxic minerals such aluminum, and can cause further acidification of the soils. All three processes may be fatal to vegetation.

EFFECTS OF ACID DEPOSITION ON THE MARINE ENVIRONMENT

Most freshwater and marine environments have sufficient amounts of sulfur to satisfy nutritional requirements for plant growth, but nitrogen inputs can often fall short of growth needs (42). In some marine environments, nitrogen can be the major limitation to phytoplankton growth (43).

In a recent study marine phytoplankton growth was examined at three Atlantic Ocean locations off the east coast of North Carolina. Rainfall coming from the West (from the continental United States) had pH values from pH 3.5 to 5.5, and rainfall coming from the East (from over the ocean) had pH values from pH 5.5 to 6.8. Over a three month period (July-Sept 1984), increases in <u>chlorophyll a</u> production (a growth measurement of phytoplankton) were positively correlated with continental rainfall (more acidic rainfall) and negatively correlated with oceanic rainfall (less acidic rainfall). It was found that 30 to 70% more growth occurred during periods when the more acidic continental rain fell than when less acidic oceanic rain fell (44). This indicated that following an acidic rainfall, nitrogen limiting conditions in near-surface waters were significantly decreased, thus causing increased stimulation of phytoplankton growth.

Paerl concluded that "although pH impacts of acid rain are largely insignificant in well-buffered marine habitats, nutritive impacts are both detectable and may be of long term consequence in shaping both patterns and magnitude of phytoplankton production." (45). Potential impacts would be expected to be most significant in waters bordering the downwind coast of land masses that supported extensive industrial and urban development. Such areas would likely include the eastern seaboard of the United States and the United Kingdom, the Baltic region and the Western Pacific waters bordering Japan, Korea and China.

MISCELLANEOUS EFFECTS OF ACID DEPOSITION

Air pollutants are one of numerous environmental factors that accelerate material damage. Acid deposition corrodes metals and paints, dissolves building stone, and degrades materials such as textiles, leathers, ceramics and rubber. Acid deposition has caused the well publicized damage to historical artifacts such as the Taj Mahal, the Acropolis, numerous cathedrals and the United States Capital building (46).

There are numerous less publicized affects of acid rain. These include visibility impairment (47), direct health risks such as respiration disorders (48), and indirect health risks such as increased toxic metal concentrations in groundwater and drinking water (49).

LONG-RANGE TRANSPORT AND IDENTIFICATION OF EMISSION SOURCES

By far the most controversial question in the acid rain issue is which sources of pollution are responsible for acid rain in affected areas such as the Northeast and elsewhere in the United States and Canada. Or, more realistically, to what extent does each source contribute to the problem. Presently, answering this question is by far the most important step towards developing effective control strategies and resolving the issue of equity.

It is known and accepted that each state causes some of its own acid rain through local emissions of sulfur dioxide and nitrogen oxides. It is also known that pollutants can be transported in the atmosphere many hundreds to many thousands of kilometers. This has been demonstrated numerous times by researchers who study long-range transport of regional anthropogenic pollutants.

Atmospheric pollutants have been reliably used as tracers of aerosols from Europe to points north or even over the North Pole to northern Alaska (50), from eastern United States to Bermuda (51), from point-sources such as Sudbury, Ontario to Narragansett, RI (52), and from Noril'sk, USSR to

Barrow, Alaska (53). The currently unsolved task is for researchers to accurately determine how much each area contributes to the pollution of another area.

Many states east of the Mississippi emit as much sulfur as is deposited locally by acid deposition (table 4). This implies that these states may produce their own acid rain. However, several states, such as Vermont and Arkansas, receive far greater amounts of acid than they emit, implying the excess has been transported in.

Factors affecting long-range transport of air pollutants include wind speed, weather variables, stack height and chemical state of pollutants, etc. One of the most important factors is the elevation at which pollutants are released into the atmosphere. If the pollutants are emitted into the mixed layer (0 to 3,000 ft) where there is adequate mixing, then the pollutants will fall to the ground quickly resulting in acid deposition close to the source. If, however, the pollutants enter the atmosphere above the mixed layer, as in the case of emissions from superstacks, then they are decoupled from the mixed layer and may be transported hundreds of kilometers by strong atmospheric winds aloft. The recent explosion in public awareness of acid rain in the Northeast has primarily been due to the

Table 4 Sulfur Emissions and Wet Sulfur Deposition in the Eastern U.S. for 1980 (As Sulfate)

State	Emissions		Wet Deposition	
	Total *(tonnes x 10^3)*	Density *(tonnes/sq. mi.)*	Total *(tonnes x 10^3)*	Density *(tonnes/sq. mi.)*
Maine	134.2	4.0	155.6	4.68
New Hampshire	148.6	16.0	52.6	5.65
Vermont	20.5	2.1	(57.7)	(6.0)
Massachusetts	651.4	78.9	(49.5)	(6.0)
Rhode Island	43.8	36.0	(7.3)	(6.0)
Connecticut	203.3	40.6	(30.1)	(6.0)
New York	1471.2	29.7	341.4	6.88
New Jersey	493.6	63.0	(47.0)	(6.0)
Pennsylvania	2953.1	65.1	424.8	9.37
Delaware	123.8	60.2	(12.3)	(6.0)
Maryland	450.0	42.5	(63.5)	(6.0)
Virginia	445.5	10.9	189.9	4.65
West Virginia	1491.3	61.7	274.0	11.33
Kentucky	1510.9	37.4	(323.2)	(8.0)
South Carolina	430.4	13.9	190.0	6.15
North Carolina	843.4	16.0	335.0	6.37
Tennessee	1480.9	35.1	309.3	7.32
Georgia	1142.3	19.4	355.1	6.03
Mississippi	267.4	5.6	319.6	6.70
Alabama	1008.8	19.5	(309.6)	(6.0)
Florida	1273.2	21.7	206.9	3.53
Arkansas	107.6	2.0	(318.6)	(6.0)
Missouri	1839.0	38.5	(418.1)	(6.0)
Louisiana	355.3	7.3	(291.1)	(6.0)
Illinois	2090.2	37.1	423.0	7.50
Indiana	2836.1	78.1	(308.5)	(8.50)
Ohio	3821.7	92.7	425.3	10.3
Michigan	1270.5	21.8	342.8	5.89
Wisconsin	843.8	15.0	(224.6)	(4.0)
Minnesota	400.9	4.8	264.7	3.15
Iowa	469.5	8.3	(225.2)	(4.0)
TOTAL	30,628.1		7,296.3	

Source: Final Emissions Inventory by U.S./Canada Work Group 2, Report No. 2-4 (Draft), September 4, 1981; and National Atmospheric Deposition Program Network for 1980. Numbers in parentheses are estimated values, interpolated from adjoining states.

Source, Acid rain and transported air Pollutants, Off. of Technol. Assess. Washington. D.C., OTA-O-204 (1984).

installation of numerous superstacks on electric power generating stations. These tall stacks carry gases up and away from local areas only to eventually be deposited in someone else's back yard (the Northeast). Although the superstacks were intended to remedy the acid rain problem, they have only moved the problem further from its place of origin.

There are three principal methods of deriving the origin of airmasses and their transported air pollutants; computer simulations, back-trajectories and trace-element analysis.

Computers models available today are able to estimate the distance air pollutants are carried downwind from their point of origin or from their region of origin. Factors taken into consideration include; wind speed and direction at different altitudes, rate of emission, temperature of emission, local and regional atmospheric condition, height of stack, etc. Another factor that must be estimated and entered into this type of calculation is the removal rate of a given amount of the pollutant. Deposition-rate calculations involve as many estimated variables as does transport-distance calculations. The magnitude of the compounded uncertainties from the numerous variables used renders the final result of the computer program only a ballpark estimate.

Back-trajectory analysis is another means by which the transport path of air pollutants can be estimated. This method relies primarily on weather maps and satellite data. to trace weather systems as they form, are transported and break down. This information will be combined with information gathered from monitoring the chemistry of each rainstorm and snowstorm at sites between the suspected source and destination. Correlating the two results gives an idea of the origin of the airmass. This method is also not absolutely reliable because of the uncertainties in rain sampling and analysis techniques as well as the great uncertainty in back-trajectory extrapolation over time periods greater than a few days.

Trace-element analysis is a newer method to determine the source area of atmospheric pollutants. This technique is indirect in that measurements are made of other trace elements associated with sulfur, and by this the sulfur's origin is inferred. The premise on which this technique is based is that each source or source region has a characteristic chemical "signature" depending on the type and amount of fuel burned. This signature remains with the airmass as it is transported. This method is similar to a method sometimes used in tracing vessel-source pollution. A technique called "chemical fingerprinting" has successfully identified specific vessels as the source responsible for a specific pollution event. Chemical fingerprinting uses the ratio of certain elements or isotopes of elements to other elements or isotopes of elements. As in the case of emission sources, vessel fuels and fuel cargos often have unique a chemical compositions that allows one fuel to be distinguished from another.

An elemental tracer system was developed in the late 1970's and early 1980's out of the necessity to explain the origin of very high concentration of anthropogenic elements in the winter Arctic aerosol, an environment previously thought to be pure and pristine. This tracer system proved to be very reliable in determining the source region of arctic haze. The original 2-element tracer (Mn/V) was developed by Dr. Kenneth Rahn at the Graduate School of Oceanography, University of Rhode Island (54). As time passed, this system was improved and expanded into a much more powerful 7-element tracer system. With this 7-element system it appears possible to distinguish northeastern and midwestern contributions to pollution aerosols in the northeastern United States.

For example, emissions from coal fired-power plants are relatively high in the element selenium, whereas oil-fired power plants are relatively low in selenium. Selenium behaves quite similarly to sulfur in an airmass. Measuring the concentrations of these elements in an airmass indicates whether that airmass originated in an area with coal-fired power plants (predominantly found in the Midwest) or oil-fired power plants (predominantly found in the Northeast).

These three methods of determining the source area of sulfur causing acid rain in the eastern United States do render similar, yet not identical conclusions. It is the magnitude of the sulfate transported from any one area that is still strongly disputed.

Computer simulations have determined that the sulfate causing acid rain comes from outside the Northeast, primarily from sources located in the Midwest/Ohio Valley. One study estimated that 87% of the sulfate in New York and New Jersey comes from long-range transport and that 92% of the sulfate in New England is transported into the region. This model also estimates that 10% of northeastern sulfate is caused by New York and New Jersey emissions, the remainder is from other sources (55).

Back-trajectory techniques have resulted in similar but not identical. One study carried out at Whiteface Mountain in New York's Adirondacks concluded that in a one year period, 62% of the sulfate in rainfall originated in the Midwest/Ohio Valley, 25% came from the Sudbury, Ontario region of Canada, and less than 5% came from the Northeast (56).

Both of these results indicate that in order to reduce the sulfur found in rain in the Northeast, one must reduce sulfur emissions in the Midwest and Canada. This implies that a complete halt of sulfur dioxide and nitrogen oxides emissions in the Northeast would have negligible affect on acid rain in the Northeast.

Conclusions from the element tracer technique differ from the other two methods. The tracer system has shown that polluted aerosol in the Northeast is composed of a Northeastern "foreground" aerosol into which pulses of midwestern aerosol are superimposed. When these midwestern pulses are very strong, the northeastern aerosol has a classic midwestern signature. When there is stagnation in the Northeast, local emissions can produce concentrations that rival or exceed those seen during in midwestern pulses, for both sulfur and trace elements. Dr. Rahn has concluded that the Northeast and Midwest contribute comparably to ambient levels in the Northeast (57). This conclusion implies that in order to reduce the acidity of rain in the Northeast, emissions must be reduced in both the Midwest and the Northeast, not solely the Midwest. Because of the less than simple conclusions, this method has been very controversial within both the scientific and political communities.

The different conclusions drawn from these three techniques cause inumerable problems for policy makers attempting to address the acid rain problem.

TECHNOLOGY FOR REDUCTION OF SULFUR AND NITROGEN OXIDE EMISSIONS

There are three general approaches for controlling acid-causing emissions.

A) Before-Combustion Methods: reduction of sulfur or nitrogen in the fuel being burned either by using fuels naturally lower in sulfur and nitrogen content, or by subjecting fuels to physical or chemical processes that remove sulfur and nitrogen;

B) During-Combustion Methods: alteration of the combustion process to reduce amounts of sulfur and nitrogen compounds released in the gas stream; and

C) After-Combustion Methods: the products of combustion can be treated to remove pollutants before they are released into the atmosphere.

Sulfur and nitrogen oxides will be considered separately.

SULFUR OXIDES

Before-Combustion Methods

Fuel-switching

The higher the concentration of sulfur in the original fuel, the greater the production of sulfur dioxide gas. One way to minimize this is to use more expensive grades of fuels with lower concentrations of sulfur (fuel-switching).

The degree of emissions reduction attainable by fuel-switching at a given plant depends on the difference between the concentration of sulfur in the original fuel being burned, and in the fuel available for replacement.

The cost of coal switching is dependent on fuel price differential and the type of fuel handling facilities and control devices. Low sulfur coal is more expensive than high sulfur coal. Compounding the expense differences is the fact that many low-sulfur coals have high ash content and require other forms of pollution control devices (electrostatic precipitators or bag houses). Other alterations may be required because of different physical properties between high and low sulfur coal.

Coal Cleaning

Sulfur exists in coal in two major forms: organic and inorganic. Inorganic or "pyritic" sulfur can be removed at minimal expense by using differences between physical properties of pyrite (Iron sulfide minerals) and coal particles. Organic sulfur is chemically bound to the carbon molecules of coal, thus making cleaning difficult and expensive.

Physical Coal Cleaning (coal washing) takes advantage of coal's physical properties; size, density, and surface properties. Coal is crushed to small size pieces, then density difference will separate pyrite from coal. This is done by flotation of the less dense coal in a solvent in which the denser pyrite sinks.

Emission reduction potential of physical coal cleaning depends on the ratio of pyrite to organic sulfur, and the efficiency of coal-cleaning techniques. Pyritic sulfur accounts for 30 to 70% of the total sulfur in coal.

A Department of Energy contract assessed the cost and emissions reduction potential of washing coal delivered to 50 large emitters in the United States. Sulfur dioxide removal efficiencies ranged from 3 to 34%. Cleaning of the coal used by the 50 plants was estimated to yield a 1.5 million-ton reduction in sulfur dioxide emissions (approximately 7% of total sulfur dioxide emitted in the Eastern United States).

Chemical coal cleaning can remove a greater percentage of sulfur contained in coal because under some circumstances this process removes organic as well as pyritic sulfur. However, this process has as yet only been successful at laboratory scale, and it is estimated to be 5-10 years before it becomes economically feasible.

Two potential chemical coal-cleaning processes are the Meyers Process and microwave desulfurization. The Meyers Process can remove 80-99% of pyritic sulfur. This is greater than with physical cleaning methods, the drawback is that this process cannot remove organic sulfur (58). Microwave desulfurization can remove organic sulfur as well as pyritic sulfur. Laboratory tests have achieved removal of greater than 90% of the total sulfur (59).

During-Combustion methods

Limestone Injection Multi-Stage Burners (LIMB)

This technique is thought to be the most promising technique available because it controls both sulfur dioxide and nitrogen oxide emissions. LIMB is based on a stage burning process for nitrogen oxide control, combined with sorbents (usually limestone), that are injected through the burners, for sulfur dioxide control. Sulfur dioxide reacts with the limestone and forms a solid (calcium sulfate). This technique is still in the developmental stages and cost efficiency is not yet known. Estimates are for 50-70% removal of sulfur dioxide and nitrogen oxide.

Fluidized Bed Combustion (FBC)

FBC removes sulfur dioxide during the combustion process. This process can remove up to 90% of the sulfur dioxide. Cost effectiveness of FBC are estimated to be about equal to a conventional boiler using flue-gas desulfurization (see after-combustion approaches). For large scale use, further research is needed. For small scale use, (up to 250 MW) this method is used and is economically feasible.

Fluidized bed boilers have the advantage of greater energy efficiency, combustion temperatures (keeping the nitrogen oxide products low), and small boiler size. Fluidized bed boilers burn both high- and low-sulfur coal.

After-Combustion Methods

Flue-gas Desulfurization (FDG or 'Scrubbing')

Scurbbing removes the sulfur dioxide gases during combustion. This is achieved by spraying the exhaust gases in the stack with a chemical absorbent, usually lime or limestone. There are three types of scrubbing systems - wet, dry, and regenerable.

Wet scrubbers are the most widely used method in the United States. Presently, over 100 scrubbers are in use (60). Limestone scrubbing is the cheapest, simplest and best developed wet-removal process of sulfur dioxide available. This technology has been commercially available for approximately ten years. As of March 1981, 5.1% of the total installed generation capacity (and 14% of coal fired capacity) has wet scrubber control. Scrubbers using lime and limestone for absorbents can remove between 70-90% of the sulfur dioxide formed during combustion. With addition of another chemical (adipic acid) efficiency can be increased to 95% (61). However, addition of adipic acid presents additional sludge disposal problems.

A 1980 Tennessee Valley Authority study estimated the capital costs of a wet limestone system using low-sulfur western coal (0.7% sulfur, 9,700 Btu per lb) ranged from

$168 to $176 per kW. In contrast, capital costs for high-sulfur eastern coal (3.5% sulfur, 11,700 Btu per lb) ranged from $236 to $294 per kW.

The cost of retrofitting an existing plant with a wet scrubber depends on the age and expected lifespan of the plant. Higher annual revenues are required to recover the capital costs of retrofitting a plant with a shorter expected life. Economics of scale in construction also render retrofitting a scrubber onto a large unit less expensive than a small one.

The major disadvantage of wet scrubber systems is the large volumes of sludge produced. This sludge is mainly calcium sulfite and sulfate and has the consistency of toothpaste, making it difficult to dewater, store, and handle. Waste produced by a typical 1,000 MW plant using 3.5% sulfur coal is approximately 225,000 tons per year (in wet form). Estimates indicate that the United States will produce more sludge from FGD scrubbing than from treating municipal sludge (62). Research on chemical treatment of the sludge to facilitate handling is underway.

Dry scrubber use has increased significantly in the past several years, despite only recent introduction into large commercial sized facilities. This process involves injection of a dewatered slurry of lime or soda ash into the flue gas. The lime or sodium carbonate reacts with sulfur dioxide to form a dry, solid product which can be collected with the fly ash in an electrostatic precipitator or fabric filter (bag house).

Dry scrubbers have several advantages over wet scrubbers. Although, dry scrubbers produce a larger volume of waste, the waste is in dry form and is handled and recycled more easily than wet sludge. Equipment for handling dry waste is simpler, requires less maintenance, has a lower capital cost and requires less energy to operate. Also, because dry scrubbers require less water than wet systems, they are more desirable in areas with a limited water supply. Among the disadvantages of dry scrubber systems are that they require expensive processed lime rather then less expensive limestone.

A Tennessee Valley Authority study has estimated that capital costs for dry scrubber systems range from $144 to $160 per kW for low sulfur western coal, and from $180 to $188 per kW for high sulfur eastern coal. Research is being done to find other dry injected minerals to replace lime, thus lowering the cost.

A new concept, that of regenerable FGD processes, is to reclaim the sulfur dioxide in powerplant flue gases using chemical to produce a marketable product. The primary benefit is that the product could be resold, thus avoiding waste disposal problems associated with wet and dry processes. The process produces either sulfuric acid or elemental sulfur. Unfortunately regenerable processes cost about 30-50% more than recoverable processes. Also, regenerable scrubbers are in the early stages of commercial development and have not yet been demonstrated to have as high a degree of removal as wet and dry scrubbers.

NITROGEN OXIDES

Two processes form oxides of nitrogen during combustion. Similar to sulfur dioxide formation, nitrogen oxides are formed as a result of the oxidation of nitrogen present in the fuel (fuel nitrogen oxide), as well as oxidation of nitrogen in the surrounding air (thermal nitrogen oxide). Both processes are oxygen limited and thermal nitrogen oxide formation is controlled by temperature. The proportion of thermal to fuel nitrogen oxide produced varies from fuel to fuel. The Electric Power Research Institution (EPRI) estimates that between 20 to 40% of nitrogen oxide emissions are thermal and 60 to 80% are fuel (63).

Nitrogen oxide emissions are dependent on the amount of oxygen present during combustion and the temperature of combustion. Thus, nitrogen oxide emissions can be most directly controlled by modifying combustion conditions. Most of these control techniques focus on the combustion process. After-combustion techniques (flue-gas treatment) are also being developed to achieve even lower emissions. Combustion techniques that are most promising are certain types of fluidized bed combustion units (already discussed), and low-nitrogen oxide burners.

During-Combustion Method

Combustion Modification

Thermal nitrogen oxide formation can be minimized by regulating the combustion temperature. This is achieved through delayed mixing of fuel and air in the combustion chamber. Regulating fuel nitrogen oxide requires control of the fuel-air ratio throughout the entire combustion process. The two major techniques used in combustion modification are "low excess air" (LEA) and "low-nitrogen oxide burners". Both processes reduce both fuel and thermal nitrogen oxide). Other techniques also used are stage combustion (off stoichiometric firing), overfire air, flue-gas recirculation low air preheat, and water injection (64).

The LEA process involves reduction of the combustion air to the minimum amount needed for total combustion. Thus, less oxygen is available for nitrogen oxide formation. LEA requires no new hardware and can achieve emission reductions merely by changing operation procedures.

A second generation of the LEA process is the low-nitrogen oxide burners. The amount by which nitrogen oxide emissions can be reduced depends on very site-specific factors, such as type of fuel burned, type of boiler used and age of plant. Problems are corrosion and high maintenance requirements. These have delayed large scale use of the low-nitrogen oxide burner.

Another combustion modification approach for nitrogen oxide is the LIMB (already discussed). EPA's objectives for the LIMB are 50-70% removal of sulfur dioxide and nitrogen oxide, however, the LIMB is not expected to be available for approximately three to five years from 1984(65).

Post-Combustion Method

Flue-gas treatment (FGT)

Flue-gas treatment (FGT) is a new method of postcombustion removal of very high levels of nitrogen oxide. Numerous types of FGT's are available today. The selective catalytic reduction (SCR) method removes the large amounts nitrogen oxide. SCR is a dry process, producing no solid waste, and it is fairly easy to retrofit existing plants. Two serious problems associated with this process are the disposal of spent catalysts (vanadium or titanium), and condensation of bisulfate and bisulfide residuals onto equipment.

NEW TECHNOLOGY

A new low polluting technology for generating electricity from high-sulfur coal is being tested at its first full-scale commercial plant in Dagget, California. This technique is probably the cleanest coal-fired power generating facility now in commercial operation and is seen as the leading long term solution to the acid rain problem (66).

In the new method, pulverized coal is mixed with water and oxygen and is converted into gas in high-temperature, high-pressure vessels. Combustion of the gas will drive a turbine generation 65 megawatts of electricity. Heat from the coal gasification process converts water into superheated steam which drives another 55 megawatt turbine. Twenty megawatts is needed to run the operation, primarily to extract oxygen from air. Thus, the combined output is 100 megawatts. Typically a conventional coal-burning plant produces 500-700 megawatts.

According to Dwain F. Spencer, Vice President for advanced power systems at the Electric Power Research Institute (EPRI), the chief investigator in the plant, the plant emits no more than 0.14 to 4 tons of sulfur dioxide per year for each megawatt generated (67). By comparison, plants burning pulverized coal using precipitation to clean stack gas emit 140 tons of sulfur dioxide per year per megawatt and plants with flue gas desulfurization emit 14 tons. Another relatively nonpolluting technology, atmospheric fluidized bed combustion, produces 7 tons (68).

Because sulfur is extracted from the gas before it is burned, the plant is relatively nonpolluting. The plant has been able to burn coal containing as much as 3.5% sulfur and give off only very small amounts of sulfur, amounts far below currently allowed federal standards. Also, the cost of this new process is expected to be about 10% less than power generated by coal burning plants that must limit pollutants with conventional stack scrubbers.

The ability of this process to allow the use of the vast reserves of high-sulfur coal from the East and Middle West with minimal adverse environmental effects "has some very promising implications for the resurgence of Appalachia" says Dr. Spencer (69).

This plant, known as the Cool Water Coal Gasification Program, built on the Cool Water Ranch, was constructed in 28 months, far more quickly than conventional plants. This plant is to complete its five-year test in 1989. One indication of the seriousness with which the industry is considering this promising new method for utilizing coal is the recent formation of the Utility Coal Gasification Association, whoes 35 utility members represent approximately half of all U.S. generating capacity. It is expected that by mid-1986 such utilities could proceed with comfidence to build a fully commercial plant, using the database established at the Cool Water plant. The Potomac Electric Power Company has already announced plans to install a 360-MWe integrated combined cycle gasification power plant onto its system located near Washington, D.C. for operation in the 1990's (70).

DEVELOPMENT OF UNITED STATES AIR POLLUTION REGULATIONS

EARLY HISTORY

In the United States, air quality regulations have existed since 1881 when the cities of Chicago and Cincinnati passed smoke control ordinances (71). Over the following 31 years, 23 other cities passed similar ordinances. The aim was to decrease the smoke resulting from burning of coal. Air quality problems became more severe in the 1930's and 1940's. This led to stricter and more effective controls in many cities. Prior to the 1950's, there was no Federal Government involvement in air pollution control, in fact very little state government involvement at all. Air pollution control was left primarily to the local governments.

In 1955, the Federal Government authorized the Public Health Service (Department of Health, Education and Welfare) to undertake air pollution research and training programs, and to aid state and local governments. Federal legislation stipulated that state and local governments had the primary responsibility for air pollution control (72).

By 1963 the nation's air quality had deteriorated to a level where Congress found it necessary to pass the 1963 Clean Air Act (CAA) (73). This legislation greatly expanded the federal role in air pollution control. The Act provided for: 1) awarding grants for improvements to state and local air pollution control agencies; 2) accelerated research, training and technology development; 3) federal enforcement authority to lessen interstate air pollution problems; 4) federal research funds for studies of sulfur dioxide and automobile emissions; and 5) air quality criteria development for the protection of human health. The Act, however, did not take the burden of responsibility off the state and local governments. Even with the 1963 Clean Air Act, primary responsibility still remained with state and local governments.

A 1965 amendment to the Clean Air Act (74) established the National Air Pollution Control Administration (NAPCA) within the Department of Health, Education and Welfare, that was to provide regulatory leadership for state and local governments. Nevertheless, air pollution remained serious even after the 1965 amendment. In 1967, Congress strengthened control efforts by enacting the Air Quality Act (75). This act was particularly important because it instituted a regional approach for air pollution control and for development and implementation of air quality standards. The 1967 Air Quality Act required the Secretary of Health, Education and Welfare to designate Air Quality Control Regions and issue Air Quality Criteria and Control Technique Information. After the federal agency completed these requirements, individual states were to develop standards of state air quality and plan fixed time schedules for their implementation. The 1967 Air Quality Act also guaranteed continuation of federal involvement in air pollution research and development, training programs, and grants to state and local air pollution control programs. The Act gave the Federal Government substantial authority to initiate legal proceedings whenever violations occurred. However, on most matters states maintained primary responsibility for enforcement.

Action under the Air Quality Act was very slow. Before states could set air quality standards they needed to wait for the federal government, under NAPCA, to designate Air Quality Control Regions and issue Air Quality Criteria and Control Technique Documents for specific pollutants. These procedures took time, often several years.

During the 1960's the Federal Government was expanding its jurisdiction and began to take control of many programs formerly under state jurisdiction. Even so, control of air pollution was still perceived to be the responsibility of state and local governments. As the 1960's progressed, it became apparent that many state and local governments lacked the necessary information, willingness and legislative ability to establish and enforce air quality standards. It was this lack of action, as well as growing public opinion, that forced the Federal Government to increase its role in air pollution control.

The increasing involvement of the federal government was a subtle but substantive change in the nation's environmental management system. These changes were characterized by the enactment of the National Environmental Policy Act (76) signed on 1 January 1970. This was the beginning of a national trend towards increased awareness of the need to protect the environment through legislative action. Prior to 1970, the few federal programs concerned with environmental issues and protection were located in various agencies of the federal system. With the Federal Government's increasing involvement in environmental control, it became apparent that there was a need to combine the various anti-pollution programs into one agency. The result agency was the Environmental Protection Agency (EPA).

1970 CLEAN AIR ACT AMENDMENTS

Passage of the Clean Air Act Amendments of 1970 (77) completed the transfer of authority from state and local governments to the Federal Government. Air pollution control efforts were now almost completely under the auspices of the EPA. The Agency was given the authority to set standards, as well as the timetables to achieve these standards, and to enforce them. The target of the 1970 amendments was to achieve "clean air" for all regions by 1975.

Several of the more significant provisions of the 1970 Clean Air Act Amendments included 1) federal designation of uniform National Ambient Air Quality Standards, (NAAQS), 2) federal designation of Air Quality Control Regions, 3) federal designation of emission standards for new or modified sources of pollutants, 4) federal rights of enforcement in air pollution emergencies and interstate or international air pollution violations and 5) authority for approval of State Implementation Plans (SIPS) necessary to achieve NAAQS. A brief description of the various terms follows.

Air Quality Standards

Under the 1967 Air Quality Act, states were required to set air quality standards for their regions. These standards were to be consistent with air quality criteria issued by the federal government under the NAPCA. This process was extremely slow. In addition, States were reluctant to adopt stringent air quality standards for fear industries in neighboring states would be subject to less stringent standards. This resulted in confusion and inaction.

The 1970 Clean Air Act Amendments gave the Federal Government the responsibility of developing uniform NAAQS. These were to take into account public health and welfare. In 1971, EPA released national ambient air quality standards for 6 classes of air pollutants, (carbon monoxide, nitrogen dioxide, sulfur dioxide, suspended particulates, hydrocarbons and ozone)(78), lead was added in 1978 (79).

Air Quality Criteria

Prior to setting the NAAQS, air quality criteria must be published. This information is to summarize all pertinent scientific information on the health effects of the pollutant. The purpose is to provide good scientific evidence on which to base the NAAQS.

Air Quality Control Regions

The concept of air pollution control on a regional scale began in 1967. It was realized that air pollution does not respect political boundaries and thus was an interstate problem. The 1970 Clean Air Act Amendments required that interstate Air Quality Control Regions be established.

State Implementation Plans (SIPs)

After publication of NAAQS, individual states are required to submit to EPA plans detailing how the state will implement, enforce and maintain the standards. These SIPs can be rejected either partially, in which case they must be revised, or totally, in which case EPA will develop a SIPs for that state.

New Source Performance Standards (NSPS)

This amendment to the Clean Air Act required that new or modified existing sources must comply with NSPS. These emission standards were to comply with the best available system for emission reduction, taking cost into consideration. Although the formation of NSPS was a federal responsibility, EPA had the authority to delegate enforcement of the NSPS to a state with an accepted implementation plan.

1977 CLEAN AIR ACT AMENDMENT

By 1975, although some site specific improvements in air quality had been made, most control regions had not yet met a single NAAQS issued by the federal government. Also, there was a rapidly growing controversy over the phenomenon called acid rain. In response to this, Congress in 1977, after considerable debate, amended three sections of the Clean Air Act, sections 110, 115, and 126 (80). Section 110 and 126 pertained to interstate transportation of acid pollutants and section 115 pertained to international transport of acid pollutants.

Interstate Pollution Control, Sections 126 and 110

The 1977 Clean Air Act Amendments made the first real attempt to deal with long-range transport (interstate) of air pollutants. Although standards may have been set on a regional basis before 1977, there were no provisions dealing with out-of-state transport of pollutants. Section 110(a)(2)(E) (81) of the 1977 Clean Air Act Amendments required that states adopt SIPs for stationary sources that would 1) attain and maintain NAAQS within their borders and 2) Prevent Significant Deterioration (PSD) in areas already meeting NAAQS. The PSD doctrine identified geographic areas having air quality better than national standards. Clean air areas, none of which followed political boundaries, were divided into three classes, Class I, II and III. Class I contained areas of national parks and primitive, and wilderness areas. Deterioration of air quality in these areas (especially Class I) by emissions from surrounding regions became the cause of much interstate controversy. Section 110(a)(2)(E) also specified that SIPs must include provisions that prohibit any state from emitting pollutants that would hamper achievement of NAAQS or interfere with PSD in another state. Although section 110 appears to address the issue of interstate pollution, the problem is far more complex, and involves far more than simply setting emission standards. The following example demonstrates one of the many intricacies involved.

During the development of section 110, Congress agreed that the section should be adopted. The more difficult step was to determine whether it would be the State Government or the Federal Government (EPA) that would have controlling authority. This was addressed by two bills that competed directly in the House of Representatives. One bill was offered by Congressman Breaux of Louisiana, the other was offered by Congressman McKay of Utah (82). Both bills were concerned with sulfur dioxide and particulates, and both proposed emission variances in the SIPS standards that would allow emissions to vary five percent of the operation time (18 days per year). The important difference between the two was that the bill offered by Breaux from Louisiana, called for control by state governors, and the bill offered by McKay from Utah, called for control by the Federal Government.

Breaux's amendment would allow state governors to permit emission limits that exceeded requirements of Class I and Class II areas for 5 percent of the time; whereas, McKay's amendment, which also allowed emissions to be exceeded 5 percent of the time, applied this only to Class II areas and required the EPA Administrator to be the controlling authority. Breaux's concern was that if EPA controlled emission variances on Class I areas, development near national parks, such as the large power plant near Capital Reef National Park in Utah, would be hampered (83).

Environmentalists, being concerned with preservation of cleaner regions, favored both components of the McKay amendment: less deterioration and EPA-managed variances versus state governor-managed variances. Also representatives from regions with dirtier air did not support variances controlled by other state governors which could lead to relaxation of tight standards in undeveloped cleaner regions and therefore provide incentive for movement of industries from dirty to clean states. Another sector of the population possibly affected by this legislation was those concerned with employment in major polluting industries. This sector favored flexible standards that would protect jobs in their present locations. The consensus of this sector was that state governors, despite recognizing local preferences for environmental quality, may be far more concerned with employment in the relevant state than would the Administrator of the EPA. In the end, Breaux's amendment for state governor control was adopted (84).

There are numerous problems with section 110. Controls are for primary air pollutants (pollutants in the orginally emitted state), but there is no mention of secondary pollutants (transform products of the primary pollutants, such as those causing acidic deposition). Also, there is no guidance to the amount (concentration) of interstate pollution to be prohibited nor ways for states to prove the origin of interstate pollution. In theory, this section requires EPA to control total regional emissions. Although this amendment should have strengthened the Act considerably, substantive results of the amendment have been marginal, or non-existent.

Section 126 (85), a companion of section 110(a)(2)(E), was an attempt to permit a recourse for states believing other states were causing interstate pollution. Section 126 requires that states notify other states of any existing or proposed major stationary "sources" that "may significantly contribute" to air pollution in the other state. The section also allows a state to petition EPA if it finds that a major stationary source in another state is causing interstate pollution prohibited under section 110(a)(2)(E). If EPA agrees the source violates the SIPs then the source must be shut down within three months.

The wording in section 126, as in section 110, is very vague and ambiguous. For example, the question of whether stationary "sources" should be interpreted as "any group of sources" or "any one source" is extremely important. In 1977, the scientific community had not yet provided a model that, over a great distance, could reliably identify emissions from a single source. If the interpretation of "sources" was to be "any one source" EPA would not be able to apply section 110 to control "total regional emissions" nor would states be able to use section 126 to protect themselves against emissions from another state. However, in 1977 atmospheric transport models were sufficiently developed to trace emissions from regional sources; therefore, if "sources" were interpreted as "a group of sources" then EPA could apply section 110 to control total regional emissions and state governments could apply section 126 and protect themselves against violations of section 110 by other states.

Since these provisions were enacted, there has been no evidence that EPA has attempted to enforce them. EPA has made no effort to assess whether SIPs are in compliance with the provision, and no guidelines have been issued by EPA to instruct states how to determine if their SIPs are in compliance. Reviews of SIPs for the relaxation of emissions controls have been for individual sources, thus only local, not regional, air quality has been considered. EPA recognized the difficulty involved with identifying source areas of transported pollutants. EPA has firmly taken the position that there is not sufficient scientific information and technology to adequately assess the causes and effects of long-range transport of atmospheric pollutants. However, this attitude will soon have to change in light of numerous studies recently released demonstrating that science is now capable of documention the relationship between emissions of sulfur dioxide and nitrogen oxides and acid deposition.

In 1981, several states attempted to use the new provisions. For example, states filed under section 126, in tandem with suits under section 307 (86), for damage caused by long-range transport of emissions from multiple sources in another state (See Appendix 1, Case Study).

International Pollution Control, Section 115

Section 115 (87) of the Clean Air Act Amendments was an attempt to deal with long range international air pollution. Under section 115, the EPA Administrator can require a state to revise its SIPs in order to eliminate emissions that effect foreign countries. The Administrator can make such a determination "upon receipt of reports, surveys, or studies from any duly constituted international agency." This section requires that three steps be followed before stricter emissions standards can be imposed.

(1) The EPA administrator or the Secretary of State must determine that pollution from the United States "causes or contributes to" an air pollution problem "which may reasonably be anticipated to endanger public health or welfare in a foreign country;"

(2) The Administrator must then determine that the foreign country gives the United States similar treatment (reciprocal rights) with respect to the control of international air pollution; and

(3) Upon positive determination with respect to these two conditions, the Administrator gives formal notification to the Governor(s) of the state(s) in which the emissions contributing to the international air pollution originate (88).

However, the wording of section 115 provides no guidelines on how this section is to be implemented. As in the case of section 110 (a)(2)(e), no details are provided as to the method of determining which states are responsible for the source of the hazardous emissions, and no guidance is given for allocation of control responsibilities where two or more states are responsible for the emissions. States within the United States have attempted to activate section 115 (transboundary pollution provision)(See Appendix 2, Case Study). The position of the Reagan Administration appears to be that the section 115 process should not be continued. Thus section 115 is not considered a viable mechanism for resolution of transboundary pollution problems between the U.S. and Canada (89). Nevert90less, attempts are still being made.

In one writers opinion, the 1977 amendments were a "band-aid" reform process which may have been the only possibility at the time (90). When re-authorization of the Clean Air Act began in 1975, implementation of the Act had barely begun. Congress was no more capable in 1975 than in 1970 to reorganize the Act to efficiently and effectively set and enforce strict air quality standards on new or existing sources. Congress was not yet ready to face the controversies over cost and employment impacts of retrofitting old plants to meet stricter standards. One problem was that the older plants were major employers of millions of voters. No voters worked at plants not yet built (91).

In the years since the 1977 amendments and reauthorization of the Clean Air Act, scientific expertise on the causes, transport, effects and control technologies has increased significantly. It is recognized by most concerned parties that the present acid rain problem cannot be addressed without narrowing the gap between emission standards for existing sources and new sources. It has also become apparent that the acid rain problem will not be quickly remedied. It will take years of work and will require close cooperation between the United States and Canada. After six years of maintaining the attitude of past administrations, that further studies must be done prior to making any decisions on additional emissions reductions, the Reagan Administration is only now considering cooperation with Canada (92).

Legislative proposals to substantially reduce sulfur dioxide emissions have been introduced into each session of Congress since 1981. The most controversial issue relating to the mitigation of acid rain is economic (93). Senator John Glenn (D-Ohio) has noted "The crux of the acid rain cleanup problem has always been the cost of the cleanup and who should bear it." (94). In 1983 the EPA proposed that sulfur dioxide emissions be substantially reduced (95). These reductions would be financed by placing an emissions tax on utilities. The proposal drew strong objections from the Office of Management and Budget and the Department of Energy as to whether the controls were justified. In addition, the affected industries were unwilling to bear the financial burden. This resulted in increasing friction between the northeastern states and the midwestern states. The EPA proposal was not endorsed by the Reagan Administration primarily because of the pressures by those groups likely to be targetted by emissions reduction programs (96). The majority of the bills introduced into Congress have faced similar deaths. A major difficulty is that several disagreements must be addressed and reconciled by one bill. These concern regional disagreements about the nature of the problem, timetables for implementing programs, and most controversial, how to allocate costs of controls.

An example of the controversy over who is to pay for emission reductions is the fate of two bills introduced into the 98th Congress (97). A bill introduced into the Senate (S. 768) required substantial reductions in sulfur dioxide emissions from the 31 states east of the Mississippi. This bill would have relied on the utility rate-making process to finance emission control costs. A House bill (H.R.3400) sought to reduce sulfur dioxide emissions in the 48 contiguous states. This bill would concentrate on reducing emissions from the fifty utility power plants having the highest 1980 sulfur dioxide emissions. This would be done by requiring these plants to install flue-gas desulfurization systems (scrubbers) (98). The major difference between the two bills is that S.768 proposes that the polluters pay, whereas H.R.3400 proposes a kilowatt hour fee on all non-nuclear electric generating plants in the 48 states to fund installment of scrubbers on the 50 plants. Neither bill was passed in the 98th Congress because of mixed support (99).

Allocation of costs proposed by these two bills is especially important. Both bills proposed to reduce emissions from eight states (Indiana, Illinois, Kentucky, Ohio, Pennsylvania, Tennessee, Virginia and West Virginia) located in the Ohio River Valley. These 8 states plus states that are the major producers of high sulfur coals, largely in Appalachia, are the group affected most by both H.R.3400 and S.768 (re-introduced into the 99th Congress as S.52 (100). H.R.3400 attempts to ease the economic impact on these states by requiring scrubbers to allow continued use of local high sulfur coal, instead of forcing a shift to low sulfur coal, and by establishing a national fee to finance the fitting of scrubbers. Even so, neither bill offers enough to all regions. Both bills place the greatest economic burden on the Midwest. The Northeast was spared substantial emissions reductions but because it perceives itself as the victim, it is unwilling to pay some of the cost to reduce pollution from midwest sources.

The acid rain controversy has not seriously affected the southern states. The attitude of the southern states has been that further research is needed (101). General consensus is that emissions from the South do not significantly contribute to Northeastern/Canadian acid rain problems. On the other hand, the South produces much of the nation's high sulfur coal, thus bills calling for switching to low sulfur coal (S.52) will hurt the South's coal mining industry. The Souths' reaction to H.R.3400 is that it is unfair because emissions from the South (and West) are low relative to the Midwest and Northeast and that this bill's fee scale is based on the amount of electricity used, not emissions levels (102).

Western views on this problem are similar to southern views. H.R.3400 proposed restrictions on growth of western coal used as well as requiring the West to help finance cleanup efforts in the East. This is resented by the West (103).

Considering the views of the various regions it is understandable why the National Governors's Associations position statement agreed that a reduction of sulfur dioxide emissions below 1980 levels within 13 years after enacting legislation was needed, but could not agree upon who should pay and what formula to use (104).

Congressional action is not the only avenue that states have to reduce sulfur dioxide emissions. States themselves can enact unilateral steps to reduce emissions from sources within their boundaries (105). New York was the first state to enact a Acid Deposition Control Act specifically to curb acid rain precursors(106). This Act is not specific as to how reductions are to be achieved, nevertheless, plans are being developed to achieve a 12% reduction from 1980 levels by 1988 and 30% reductions by 1991. Massachusetts made several attempts in 1984 to pass legislation to curb acid rain. None were adopted due to lack of consensus as to methods of financing. Instead, Massachusetts allotted $500,000 of its 1984-85 budget to research on the effects and controls of acid rain(107).

Certain states have chosen to endorse further research. The Indiana House of Representatives called for the United States Congress to increase funding of acid rain research (108). The Indiana legislature also favored targetting local sources in the Northeast for emissions reductions and providing national cost-sharing to protect Indiana coal miners. Kentucky chose a similar path. Despite individual state efforts, the regional nature of this as well as the occurence of long-range transport of the pollutants problem requires that the Federal Government take the responsibility of legislating emission reductions.

ACID PRECIPITATION ACT OF 1980

To date, Congress has made no pronouncement on acid deposition other than to encourage funding. In 1980, Congress passed the Acid Precipitation Act (109). This Act created an Interagency Task Force (110) to conduct a 10-year comprehensive assessment of the causes, effects, control methods, and control costs. In August 1981, the Federal

Government accelerated the research program. Funding was increased from $17.4 million in FY-1982 to $27.6 million in FY-1984 and to 55.5 million in FY-1985. An Assessment Plan was presented to Congress in June 1983. Under this plan, the Task Force would present a policy-related integrated assessment of the air pollution problem between 1987 and 1989.

UNITED STATES-CANADA ACID PRECIPITATION PROBLEM

Cooperation between the United States and Canadian Governments over issues concerning transboundary pollutants dates back to the late 1930's. The United States and Canada called upon the International Joint Commission (IJC), (a commission set up by the United States and Canada in 1909 to monitor transboundary water disputes between the countries) to make a ruling on a dispute over air pollution from the Trail Smelter in British Columbia (111). The United States claimed that sulfur dioxide fumes from the smelter were affecting the state of Washington. The Canadians admitted liability, however they disputed the extent of damages. They requested that the IJC (International Joint Commission) only address the question concerning the extent of the damages caused by the fumes, however the Commission's conclusion has long been remembered.

> No state has the right to use or permit the use of its territory in such a manner as to cause injury by fumes in or to the territory of another or the properties or persons therein, when the case is of a serious consequence and the injury is established by clear and convincing evidence (112).

The conflict between the United States and Canada over the issue of acid rain began in the 1970's. Resolution of this transboundary air pollution problem is far more controversial both politically and economically than was the Trail Smelter case.

The first attempt to establish a cooperative program between the United States and Canada came in 1978. The United States and Canada established a bilateral research program, (Long-Range Transport of Acid Precipitation), to coordinate exchange of scientific information on acid deposition (113). The Canadians were dissatisfied with what the United States called progress and the talks came to a halt. Throughout negotiations the United States Government officials stated that reasonable progress towards reaching a bilateral agreement had been made. However, Canadian officials expressed considerable dissatisfaction with progress, implying the United States is all talk and no action (114).

On 5 August, 1980, the United States and Canada signed a Memorandum of Intent concerning Transboundary Air Pollution (MOI) (115). Neither the United States nor Canada were legally bound by the MOI (it was done done with good intentions by both countries). The MOI established working groups to prepare three backround technical reports. These three reports, released in February 1983, were on impact assessment, atmospheric science and analysis, and emissions cost and engineering assessment of acid rain.

Despite these and many reports by various United States and Canadian agencies, the Reagan Administration has doggedly opposed all attempts to control the chief sources of acid rain. Specifically, in 1983 the Interagency Task Force concluded that even with the scientific uncertainties, action against acid rain should start immediately. Nevertheless, President Reagan ignored the advice and turned down a very modest acid rain control program proposed by William Ruckelshaus, then head of EPA (116). The Administration's policy has maintained that it is premature to act to reduce acid rain.

For several years Canada has been eager to regulate emissions. The Canadian Clean Air Act (117), most recently amended in 1980, is considerably less intricate than the United States Clean Air Act. The Canadian Clean Air Act is based on three levels of air quality; tolerable, acceptable, and desirable. These air standards are set to limit the ground level concentrations in the immediate vicinity of the emissions source. This was achieved either by decreasing sulfur dioxide emissions or by using tall stacks to disperse pollutants away from the source.

March 1985 marked a distinct change in Canada's air pollution policies. Reductions of emissions to 50% of the 1980 level were called for by 1994 (118). The Canadian Federal Government will provide financial assistance to the industrial sector in the range of $150 million and $25 million to assist in development of improved smelter technologies. With these regulations Canada feels it has made its contribution to abetting the acid rain problem. Since Canada blames the United States for much of its acid rain problem, it awaits action by the United States Government to indicate the United States is willing to assist in completely resolving the problem. The acid rain problem has been one of the most controversial political issues and has caused great animosity between the two nations.

In March 1985, during a meeting in Quebec, Canada, Prime Minister Brian Mulroney of Canada and President Reagan, named William Davis of Canada and Drew Lewis of the United States as special envoys to study acid rain. Their report was released in January 1986 (119). Prior to its release, officials indicated that the report departed greatly from the Administrations present polity on acid rain, and that if the report were to be accepted by the

Reagan Administration it would be the first formal acknowledgement by the Reagan Administration that acid precipitation from the United States was causing damage in Canada.

The report stated that acid precipitation is causing serious economic and social problems in the United States and must be addressed immediately. Also, acid precipitation produced in the United States is falling in Canada and causing damage there. The report also reiterated that there are still too many scientific uncertainties to propose immediate elimination of specific pollutants. The report did not call for a detailed program to reduce the pollution causing acid rain; but it did proposed an accelerated 5-year, $5 billion program to develop clean ways to burn coal. Half the cost of this program would be borne by the government and the other half by private industry. It is expected that the first two years of United States funding will be paid for out of existing spending authorized for acid rain research (120) A way will have to be found to reconcile the allocation of the remaining funds in light of efforts to cut the budget deficit. It seems apparent that the Administration will continue to oppose more ambitious and expensive programs that will inevitably be proposed to Congress.

During a second meeting of Prime Minister Mulroney and President Reagan on 17 March 1986, President Reagan announced that he fully accepted the January report by Drew Lewis and William Davis (121). The reason for the drastic change in policy appears to be a mixture of politics and science. The Administration's decision was made just as a National Research Council report dispelling many of the scientific uncertainties was to be released. This 500 page report, released on 21 March 1986 by the National Research Council, an arm of the National Academy of Science, was titled <u>Acid Deposition, Long-Term Trends</u>(122). This government report concluded that there was no longer any doubt that the emissions of sulfur produces acid rain and its effects are harmful to man and the environment. Still, the Reagan Administration's commitment to fight acid rain, though a victory for many critics who have urged for action on the acid rain issue, will probably fall short of the hopes of the Canadian Government.

CONCLUSION

From the review of events that have led up to the present situation, it is obvious that the issues concerning transboundary pollution, both interstate and international, will not be easily resolved.

For a number of years, state governments have been aware of and concerned about interstate pollution. Because of fierce interstate rivalry over economic impacts, such as loss of employment, cost of controls, and relocation of industries, the states have been unable to formulate joint programs to deal with the acid precipitation problem. An important issue has been the lack of concrete evidence demonstrating that emissions from one geographic area are unequivocally causing pollution in another geographic area.

Since enactment of the 1977 Clean Air Act Amendment, several states have attempted to use the only legal avenue available to protect themselves from other states' pollution, sections 110 and 123. As a result of the vague wording of the sections, as well as an inability to prove their accusations, these attempts have not been successful. Some states have chosen to legislate their own emission reduction laws. Most of these attempts have been unsuccessful due to insufficient treatment of the complexities involved, and a lack of funding. Congress has also been quite active on this issue. Numerous bills calling for emissions reductions have been submitted to Congress, yet no emissions reductions have been achieved. There has been strong support for reductions in acid causing emissions support from the public and environmental groups. Finally, there is growing concern over whether the damages already incurred can be reversed.

Despite the efforts of governmental, legislative and private sectors, the Administration has only conceded to research on the problem. However, within the past few months, there has been a subtle shift in the Administrations' policy on acid deposition. Continuing pressure from Canada appears to have impressed upon the Administration that in order to remain friendly and to continue beneficial interactions, the Reagan Administration needs to take a more active role in reducing acid Deposition. This administrative shift, however small, may be the flashing green light to the states that it is time to make a strong push to incorporate the interstate pollution issue with the transboundary pollution issue. The states, by themselves, have been ineffective in promoting change. The major issue is transboundary pollution, be it state/state or nation/nation.

Scientific information has continued to support what many of the states, and Canada, have been claiming for years. Prior to 1986, the Administration claimed that insufficient evidence existed to justify emissions reductions. Now, with that myth essentially dispelled, the state governments need to concentrate their efforts towards either restructuring the existing CAA into a comprehensive and functional Act, or to formulate a new bill solely to address the issue of transboundary pollution.

APPENDIX 1

In January 1981 New York State, Pennsylvania and Maine joined forces in an attempt to press the Federal Government into action on the acid rain issue. A combined petition was submitted to the EPA. The petition claimed that long-range transport of sulfur dioxide, nitrogen oxides and particulates emitted by major facilities in Illinois, Indiana, Kentucky, Michigan, Ohio, West Virginia and Tennessee were causing interstate pollution in violation of section 110(a)(2)(E) of the 1977 Clean Air Act Amendments. The petition claimed that pollution from these states were causing the inability of the their states to obtain NAAQS and interfering with PSD requirements. They charged that conversion of sulfur dioxide to particulate sulfate was also presenting a health hazard and causing acid rain, resulting in damage to aquatic and terrestrial ecosystems. Maine also charged that the transformed products were causing visibility degradation in Acadia National Park (Class I area).

Section 126 of the Clean Air Act authorizes the Administrator of EPA to hold public hearings within 60 days of the claim and either accept or deny the petition. If the Administrator accepts the findings, he is authorized to impose more stringent air pollution control on the facility or close them down. A hearing was held in mid-1981, and evidence was accepted even after the hearing, but no action was taken.

In March 1984, the three states plus Pennsylvania, Minnesota, Rhode Island and Vermont and three environmental groups, the National Wildlife Federation, National Resource Defense Council and Sierra Club, brought a case to the United States District Court of the District of Columbia. They requested that the Administrator of EPA be requested to act on their claim of 1981 under section 126 and force eight midwestern states to reduce sulfur dioxide emissions. Seven months later (October 1984), the Administrator was ordered to issue a final decision on the petition within 60 days. The order was issued despite the Administrators arguments that acid rain issues were so complex and controversial that is was impossible to make this deadline. The court concluded "By creating the section 126 petition process, Congress sought to establish a means of protecting citizens and the environment from the harmful effects of air pollution originating outside their home state. Defendant's delay in following his statutory mandate has compromised this process."(123)

On 5 December 1984, the Administrator denyed the States' petition claiming that the Act does not address acid rain or long-range transport effects or visibility. The consortium of states appealed this decision to the United

States Circuit Court of Appeals. No action has been yet taken on the appeal.

APPENDIX 2

In December 1980, Senator George Mitchell of Maine submitted a letter to Administrator Douglas Costle of EPA and the Secretary of State, alerting them of section 115 and calling their attention to reports prepared by the IJC and the United States-Canada Research Consultation Group on Long-Range Transboundary Air Pollution (RCG). Senator Michell reviewed the information and requested action be taken under section 110 of the Clean Air Act.

In January 1981, (the same day the consortium of states listed in Appendix 1 sent the petition to the EPA), Administratior Costel sent letters to Senator Mitchell and Edmund Muskie, Secretary of State, concluding that, based on the IJC and RCG reports, and the Clean Air Act, that action could be taken under section 115. He also determined that Canada's 1980 Clean Air Act Amendment provided Canada with the authority to give the United States essentially the same right (reciprocal rights). Having make the required determination to activate section 115. The Administrator instructed EPA staff to start work to identify which states are responsible and which governors should be formally notified, and to begin to formulate appropriately revised SIPs for these states.

Four and one-half years after the initial petition (July 1985), in a second opinion on the same case, the United States District court concluded that Administrator Costle had activated section 115 and must again determine if reciprocal rights between the United States and Canada still exists and if they do the present Administrator of the EPA must give formal notification to the Governors of the accused states and to begin proceedings to require or plan means to prevent or eliminate endangerment. The defendants (the current Administrator, National Coal Administration, and several industrial power companies) alleged that in 1981 Administrator Costle did not follow protocol for activation of section 110, and therefore it was legally invalid. The courts rejected the defendants argument and concluded "Having concluded that Administrator Costle properly invoked section 115 of the Clean Air Act, it now is incumbent upon the current EPA Administrator to "give formal notification to the Governors of the states in which the harmful emissions originate and to set in motion the necessary processes to require a plan revision so as to prevent or eliminate the endangerment encompassed by the Costle determinations," (124).

In August 1985, the EPA asked for 30 days to formulate a schedule for compliance. The EPA claimed it was unable to complete a task of such magnitude in the time alloted. The

Court's order required the Administrator to reevaluate the Canadian's Clean Air Act to assure compliance with the reciprocity issue within ninety days and to formally notify the governors within 180 days of the determination that the Canadian law provided reciprocal rights commence the proper proceedings (125). The decision is due by 1 May 1986.

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106 State Air Laws, 1986 Environmental Reporter, 461:0501.

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108 Ibid. at 500:1009.

109 Acid Precipitation Act of 1980- Title VII of the Energy Security Act, PL#96-294.

110 The Interagency Task Force is composed of heads and representatives of various agencies and national laboratories and four members appointed by the President.

111 Trail Smelter Arbitral Tribunal, Amer. J. of Int'l Law, 35 (1941) pp. 684-716.

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