Publisher's Note

As we enter the third decade of the twenty-first century, environmental issues are at the top of the urgent concerns facing the world. In *Encyclopedia of Environmental Issues*, 3rd edition, the fundamental concepts, issues, and debates are considered. This 4-volume encyclopedia is a definitive reference to environmental issues from Acid deposition and acid rain to Zoos' involvement in wildlife conservation.

From fossil fuels to renewable resources, pollution to sustainability, from Edward Albee to Howard Clinton Zahniser, the *Encyclopedia of Environmental Issues* is a roundup of environment-related curricular disciplines, including agriculture, history, sociology, energy, public policy, science, climatology, engineering, and business. Especially targeted toward high-school students, this outstanding reference work is edited to tie into the high-school curriculum, making the content readily accessible as well as to patrons of public, academic, and university libraries. Pedagogical elements include a timeline, resource guides, glossary, and thorough index.

Scope of Coverage

This academic, multi-author reference work serves as a general and nontechnical resource for students and teachers to understand the importance of the many issues related to the environment, from agriculture and engineering to disasters and breakthroughs. The intent is to gain an appreciation for the dramatic impact our interactions with the environment, negative and positive, can have on nations around the world; to learn the history of environmental studies; and to initiate educational discussion brought forth by the specific social and topical articles presented in the work. Individuals who have made significant contributions are included as well as topics related to the field of environmentalism, including important legislation, treaties, governmental action, and industry.

Article Length and Format

Articles in the encyclopedia range in length from 500 to 3,500 words. Each is first presented with the category to which it belongs (for example, Agronomy; Anthropology; or History), a statement of the significance of the topic or identification of the individual, and an article summary.

The article body contains a thorough explanation and review of the topic or the work of the individual being profiled. Each article is then followed by a "Further Reading" section that includes bibliographic citations and, where appropriate, a "See Also" section that includes cross-references to other relevant articles in the set. Many articles are richly illustrated with photos and captions, and charts, graphs, and tables. Each article is signed by the contributor to the encyclopedia.

Frontmatter and Backmatter

Volume 1 of the *Encyclopedia of Environmental Issues* begins with an introduction to the set. The "List of Articles," repeated in all four volumes, features all the articles in alphabetical order with page numbers as they are listed in the encyclopedia. The "List of Contributors" presents all the writers for the encyclopedia.

The backmatter of the encyclopedia at the end of Volume 4 includes the following:

- Glossary
- Timeline of American Environmentalism
- Key Figures in Environmentalism
- U.S. Federal Laws Concerning the Environment
- Directory of U.S. National Parks
- Major World National Parks and Protected Areas
- Environmental Organizations
- Subject Index

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■ Abbey, Edward

Fields of Study: Popular Culture, Media, Publishing; Authors, Writers; Ethics, Advocacy, Policy, Protest; Ecology, Environment, Environmentalism.

Categories: Activism and advocacy; preservation and wilderness issues

Identification: American environmental activist and author

The originality of Abbey's ideas regarding the preservation of nature, expressed with great eloquence in his writings, helped to increase awareness of environmental issues and inspired a radical environmental movement.

Over the course of his lifetime, Edward Abbey produced twenty-one volumes of fiction, essays, speeches, and letters expressing his love for the earth, his hatred of modern technological society, and his fervent belief that development was destroying the American West. When he was twenty-one years old, having spent some time in the military and in college, he left his home in Pennsylvania to see the American West. He hitchhiked, rode trains, and walked over the mountains and through the desert. He claimed the desert as his spiritual home and lived in or near it for most of the rest of his life. He completed a master's degree at the University of New Mexico and wrote his Ph.D. thesis on anarchism and the morality of violence. During his ten-year college career, which included two years as a Fulbright Fellow at the University of Edinburgh in Scotland, he began a number of writing projects and published his first novel, *Jonathan Troy* (1954).

For fifteen years, during his thirties and forties, Abbey worked as a part-time ranger at various national parks in the American Southwest. The two years in the late 1950's that he spent at Arches National Monument (now a national park) in Utah led to his first important book, *Desert Solitaire: A Season in the Wilderness* (1968). This book combines beautiful descriptive passages, an unflinching look at the violence in nature, and a strong call for the preservation of desert habitats. Reminiscent of Henry David Thoreau's *Walden* (1854) in its ideas and its use of the natural year for its structure, *Desert Solitaire* brought Abbey national attention as an environmental writer.

In 1975 Abbey published *The Monkey Wrench Gang*, a novel about four rebels who set out to destroy the roads, bridges, and power lines that they believe are defacing the southwestern desert. This work is loosely based on the exploits of a friend of Abbey who had committed some of the acts depicted in the novel. Despite the fact that Abbey consistently maintained that he intended the book primarily as humor, it helped inspire the radical environmental group Earth First!, a group that Abbey did come to support, praising its operations although never actually joining it. In fact, Abbey never joined any political or environmental organizations, although he participated in political actions, especially those that expressed disapproval of the military or land development.

Though most of his books are set in the wilderness of the Southwest and express his deep love for such spaces, Abbey disliked being called a "nature writer." In fact, students of his work have had difficulty attaching any label to Abbey and making it stick, so idiosyncratic are his ideas and connections. When Abbey died in 1989, he left instructions that he should be buried in the desert, unembalmed, in his sleeping bag. Although this kind of burial was illegal, his friends followed his wishes.

Cynthia A. Bily

Further Reading

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Cahalan, James M. *Edward Abbey: A Life*. University of Arizona Press, 2001.

Pozza, David M. *Bedrock and Paradox: The Literary Landscape of Edward Abbey*. Peter Lang, 2006.

See also: Earth First!; Monkeywrenching; Preservation.

Accounting for nature

Fields of Study: Economics; Business Management; Ecosystem Management;

Identification: The expansion of economic principles and adaptation of financial decisions to take into consideration natural resources, ecosystem services, and values derived from human contact with the natural world

In comparisons of the costs and benefits of various actions in relation to the environment, the coordination of ecological and economic expertise can result in a balanced problem-solving approach.

Environmental decisions frequently set ecologists and economists on a collision course: Does society's demand for energy justify the environmental impacts of mining and burning coal? Is the increased economic efficiency of large corporate farms worth the loss of a rural lifestyle? How much should the public sacrifice to protect endangered birds or plants? These decisions are difficult because they force comparisons of "apples and oranges," pitting one set of values against another. Quantitative models (or accounting systems) that compare the costs and benefits of a course of action are frequently used to guide business and government decisions, but these have generally omitted environmental values. Accounting for nature in these models cannot produce completely objective solutions but can help coordinate ecological and economic expertise in a more balanced problem-solving approach.

Ecologist Edward O. Wilson has identified three kinds of national wealth: economic, cultural, and biological. He has observed that nations frequently create the illusion of a growing economy by consuming their biological or cultural "capital" to create short-term economic prosperity. For example, burning rain forests and replacing them with row crops may temporarily increase farm production in a developing nation, but tropical soils are often nutrient-poor and easily degraded by exposure to the sun and rain. If the biological basis of production is ignored, the population simply transfers wealth from one category to another, ensuring ecological disaster for its children in the process.

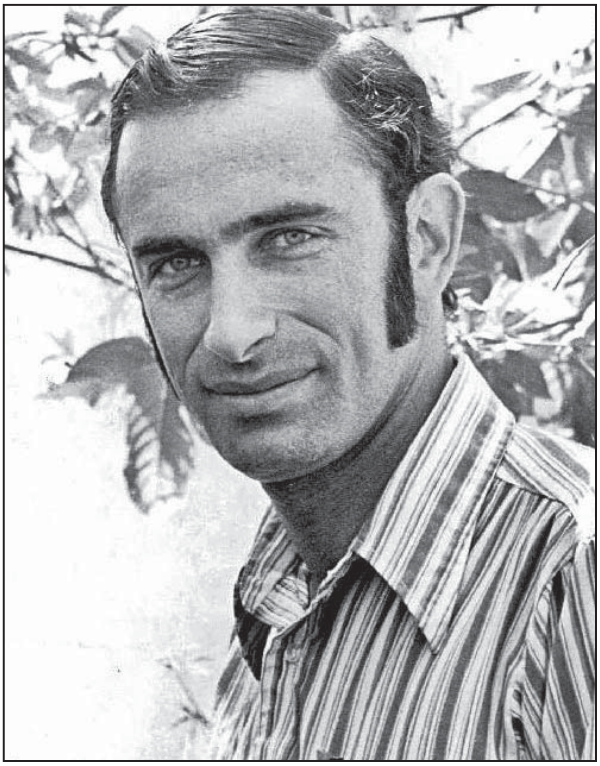

Photo of Dr. Paul R. Ehrlich, entomologist. By Ilka Hartmann (eBay).

Developed nations have also neglected biological wealth in past cost-benefit analyses. Nations have justified the damming of wild rivers to make recreational lakes, for example, by counting the benefits of lumbering trees from the watershed but not the losses of aquatic and forest habitats. Recreational activities have been evaluated according to the money that people pay to participate in them; thus hikers and canoeists in a wilderness area are given less consideration than water-skiers or drivers of recreational vehicles in a developed area because hikers and canoeists spend less money on equipment, fuel, and supplies.

Ecologists Eugene P. Odum and Howard T. Odum addressed this issue by calculating the value of ecosystem services provided by intact biological communities. Their approach was to measure the beneficial work performed by living systems and place a value on that service based on the time and energy required to replicate the service. A living tree, they reasoned, may provide a few hundred dollars in lumber if cut; if left alive, however, the oxygen it produces, carbon dioxide it absorbs, wildlife it feeds and shelters, soil it builds, evaporative cooling it yields, and flood protection it provides are worth far more on an annual basis.

In 1972, economists William Nordhaus and James Tobin refined the concept of national wealth by developing an index of net economic welfare (NEW) to replace the more familiar measurements of economic health such as gross domestic product (GDP). Their criticism of the GDP was that it counts any expenditure as a positive contribution to national wealth, whether or not the spending improves people's lives. A toxic waste dump, for example, contributes to the GDP when the pollutants are produced, again when millions of dollars are spent to clean it, and yet again if medical costs rise because of pollution-related illness. Nordhaus and Tobin's NEW index subtracts pollution abatement and other environmental costs from the value of goods and services that actually improve living standards.

Economist E. F. Schumacher subsequently argued that environmental costs should be "internalized," or charged to the industries that create them. This idea, also called the "polluter pays principle," not only generates funds for environmental cleanup but also encourages businesses to make environmentally sound decisions. The price of recycled paper, for example, would be more competitive if the public costs of deforestation and pollution from pulp mills were added to the price of virgin wood fiber. Proposals for internalizing environmental costs have ranged from centrally planned models, such as a carbon tax on fossil fuels, to free market trading of pollution credits. Debt-for-nature swaps, through which developing nations receive financial benefits for preserving natural ecosystems, represent environmental cost accounting on the asset side of the ledger.

A fundamental difference between economic and ecological worldviews is the time scale under consideration. Business strategies may look five years ahead, but ecological processes can take centuries. Thus economic models that fail to take long-term issues into account are a frequent source of criticism by environmentalists. The U.S. decision to build nuclear fission reactors during the 1960's and 1970's is a case in point. Nuclear power appeared economically attractive over the thirty-five-year life span of a fission reactor, but the twenty-four-thousand-year half-life of radioactive plutonium 239 in spent fuel rods made skeptics wonder who would pay the costs of nuclear waste disposal for generations after the plants were closed.

Debates about growth are especially contentious. Traditional economists view the growth of populations, goods, and services as positive and necessary for economic progress and social stability. As early as 1798, however, economist Thomas Robert Malthus pointed out that on a finite Earth, an exponentially expanding human population would eventually run out of vital resources. In the closing decades of the twentieth century, Paul R. Ehrlich and Anne Ehrlich warned that unless population growth slowed soon, each person would have to consume less space, food, fuel, and other materials to avoid a global population crash. Whether one considers them economic pessimists or environmental realists, Malthus and the Ehrlichs demonstrate that taking a longer view is central to the task of accounting for nature. Sustainable development is the watchword for ecologists, economists, and political leaders attempting to create prosperity today while accounting for the welfare of future generations.

Robert W. Kingsolver

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Acid deposition and acid rain

Fields of Study: Chemistry; Elements, Substances, Chemicals, Compounds; Pollution, Emissions, Toxic Waste, Hazardous Materials; Biology, Life Sciences, Ecosystems; Ecology, Environment, Environmentalism.

Identification: Deposition of acidic gases, particles, and precipitation (rain, fog, dew, snow, or sleet) on the surface of the earth

Electric utilities, industries, and automobiles emit sulfur dioxide and nitrogen oxides that are readily oxidized into sulfuric and nitric acids in the atmosphere. Long-range transport and dispersion of these air pollutants produce regional acid deposition, which alters aquatic and forest ecosystems and accelerates corrosion of buildings, monuments, and statuary.

In 1872 Robert Angus Smith used the term "acid rain" in his book *Air and Rain: The Beginnings of a Chemical Climatology* to describe precipitation affected by coal-burning industries. Acidity is created when sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react with water and oxidants in the atmosphere to form water-soluble sulfuric and nitric acids. The normal acidity of rain is pH 5.6, which is caused by the formation of carbonic acid from water-dissolved carbon dioxide. The acidity of precipitation collected at monitoring stations around the world varies from pH 3.8 to 6.3 (pH 3.8 is three hundred times as acidic as pH 6.3). Ammonia, as well as soil constituents such as calcium and magnesium that are often present in suspended dust, neutralizes atmospheric acids, which helps explain the geographical variation of precipitation acidity.

Increasing Acidity

Between the mid-nineteenth century and World War II, the Industrial Revolution led to a tremendous increase in coal burning and metal ore processing in both Europe and North America. The combustion of coal, which contains an average of 1.5 percent sulfur by weight, and the smelting of metal sulfides released opaque plumes of smoke and SO_2 from short chimneys into the atmosphere.

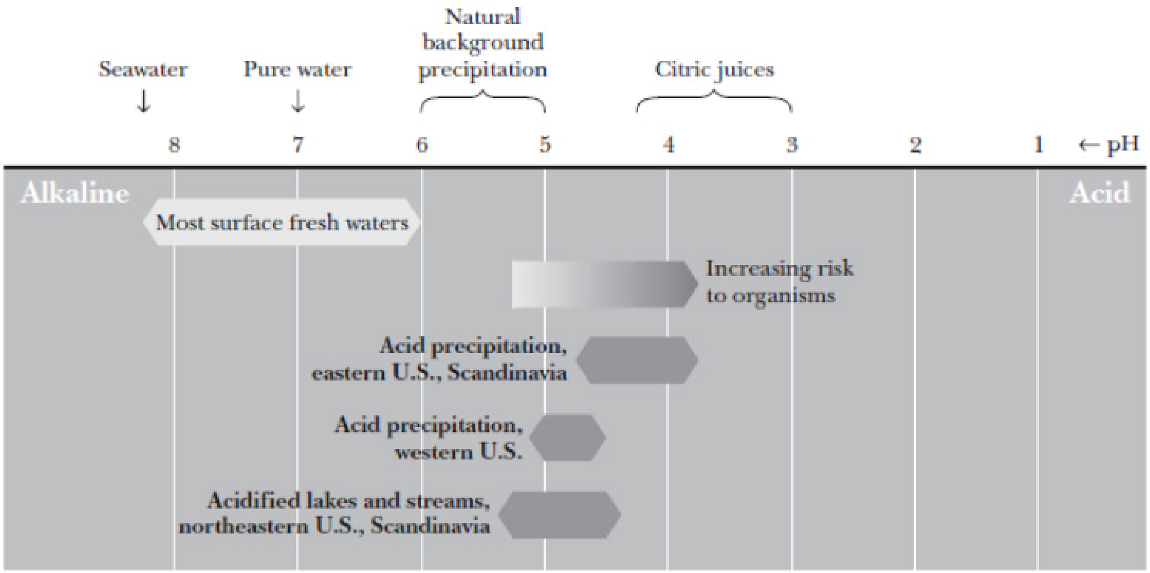
Copper, nickel, and zinc smelters inundated nearby landscapes with SO_2 and heavy metals. One of the world's largest nickel smelters, located in Sudbury, Ontario, Canada, began operation in 1890 and by 1960 was pouring 2.6 million tons of SO_2 per year into the atmosphere. By 1970 the environmental damage extended to 72,000 hectares (278 square miles) of injured vegetation, lakes, and soils surrounding the site; within this area 17,000 hectares (66 square miles) were barren. The land was devastated not only by acid deposition but also by the accumulation of toxic metals in the soil, the clear-cutting of forested areas for fuel, and soil erosion caused by wind, water, and frost heave. (The situation improved dramatically in the ensuing decades, but only after construction in 1972 of a tall "superstack" that dispersed emissions farther from the smelting facility, followed by an extensive tree-planting program and other major environmental reclamation efforts, as well as installation of industrial scrubber systems at the facility during the 1990's.)

In urban areas, high concentrations of sulfur corroded metal and accelerated the erosion of stone buildings and monuments. Historical structures such as the Acropolis in Greece suffered serious damage from elevated acidity. During the winter, added emissions from home heating and stagnant weather conditions caused severe air pollution episodes characterized by sulfuric acid fogs and thick, black soot. In 1952 a four-day air-pollution episode in London, England, killed an estimated four thousand people.

After World War II, large coal-burning utilities in Western Europe and the United States built their plants with particulate control devices and stacks higher than 100 meters (328 feet) to improve the local air quality. (By contrast, huge industrial facilities throughout Eastern Europe and the Soviet Union operated without air-pollution controls for most of the twentieth century.) The tall stacks increased the dispersion and transport of air pollutants from tens to hundreds of kilometers. While this measure eased localized impacts, it simultaneously made the problem more widespread. Worldwide emissions of SO_2 increased; in the United States emissions climbed from 18 million tons in 1940 to a peak of 28 million tons in 1970. Acid deposition evolved into an interstate and even an international problem.

In major cities, exhaust from automobiles combined with power plant and industrial emissions to create a choking, acrid smog of ozone mixed with nitric and organic acids formed by photochemical processes. The rapid deterioration of air quality in cities, with attendant health and environmental consequences, spurred the passage of environmental laws

pH Scale Showing Acidity of Acid Precipitation



Source: Adapted from John Harte, "Acid Rain," in *The Energy-Environment Connection*, edited by Jack M. Hollander, 1992.
Note: The acid precipitation pH ranges given correspond to volume-weighted annual averages of weekly samples.

such as the U.S. Clean Air Act (CAA) of 1963, which was amended and expanded in 1970, 1977, and 1990. Each amendment to the CAA brought new requirements for air-pollution controls.

Effects on Aquatic Ecosystems

Landscapes rich in limestone or acid-buffering soils are less sensitive to acid deposition. Regions that are both sensitive and exposed to acid deposition include the eastern United States, southeastern Canada, the northern tip of South America, southern Sweden and Norway, central and Eastern Europe, the United Kingdom, southeastern China, northeastern India, Thailand, and the Republic of Korea (South Korea). Within these regions, acid rain disrupts aquatic ecosystems and contributes to forest decline.

A strong correlation has been found between fish extinction and lake and stream acidity. Researchers have also found that the diversity of not only fish but also phytoplankton, zooplankton, invertebrates, and amphibian species diminishes by more than 50 percent as surface water pH drops from 6.0 to 5.0. Below pH 5.6, aluminum released from bottom sediments or leached from the surrounding soils interferes with gas and ion exchange in fish gills and can be toxic to aquatic life. At pH 5.0, most fish eggs cannot hatch; below pH 4.0, no fish survive.

In southern Norway, the virtual extinction of salmon in all the larger salmon rivers is attributed to acid rain. In 2008 it was found that twelve salmon stocks were endangered and another eighteen had been wiped out altogether. Records and long-term monitoring show that the decline of fish populations began during the early twentieth century, with dramatic losses during the 1950's. Between 1950 and 1990, fish mortality in the region became more widespread. In the three decades following 1980, pollution-control measures in Norway and the rest of Europe cut acid precipitation over Norway by roughly half. Aquatic animal and plant populations and ecosystems continue to recover from the damage.

In the United States the New York State Department of Environmental Conservation reported in 2008 that 26 percent of the state's lakes in the Adirondack Mountains were unable to neutralize incoming acids to concentrations that fish could tolerate. During certain times of year, up to 70 percent of the lakes had the potential to become intolerably acidic. Of forty-eight Adirondack lakes surveyed, sixteen had aluminum concentrations above levels that juvenile fish could withstand. Ecosystems in this region have been affected by plumes of air pollutants carried by prevailing winds from the Ohio River Valley. Like their Norwegian counterparts, the Adirondack lakes have low acid-neutralizing capacity. Fish declines that began during the early twentieth century and continued through the 1980's corresponded to reductions in pH. Fish kills often followed spring snowmelt, which filled the waterways with acid accumulated in winter precipitation.

While the CAA and its amendments have done much to reduce the acidity of the precipitation in the Adirondacks, and thus of the lakes, recovery takes time. Lake chemistry that is acidic year-round may take twenty-five to one hundred years to return to levels that aquatic life can tolerate, while seasonally acidic lake waters may take a few years or several decades. Once a lake regains its ability to neutralize acid, wildlife in the lake's ecosystem require additional time to become reestablished.

Effects on Forests and Cities

In areas exposed to acid rain, dead and dying trees stand as symbols of environmental change. In Germany the term *Waldsterben*, or forest death, was coined to describe the rapid declines of Norway spruce, Scotch pine, and silver fir trees during the early 1980's, followed by beech and oak trees during the late 1980's, especially at high elevations in the Black and Bavarian forests. At higher altitudes, clouds frequently shroud mountain peaks, bathing the forest canopy in a mist of heavy metals and sulfuric and nitric acids. Under drought conditions, invisible plumes of ozone from sources hundreds of kilometers distant intercepted the mountain slopes. Several forests within the United States have been likewise affected by both ozone and acidic deposition, including the pine forests in California's southern Sierra Nevada and high-elevation spruce-fir forests in the Northeast.

Intensive field and laboratory investigations of forest decline in North America and Europe have yielded contradictory results regarding the link between dead trees and acid deposition. Some laboratory experiments have found that acid rain has no effect, or even a fertilizing effect, on trees. Symptoms of tree stress include changes in foliage color, size, and shape; destruction of fine roots and associated fungi; and stunted growth. Many researchers attribute these symptoms and forest decline to complex interactions among a variety of stressors, including acid precipitation, ozone, excessive nitrogen deposition, land management practices, climate change, drought, and pestilence. Acid rain generally does not kill trees directly; rather, it weakens them by damaging their leaves, impairing their leaves' functionality, stripping nutrients from the soil, and releasing toxic substances from the soil.

Ambient air concentrations of SO_2 and NO_x are typically higher in major cities owing to the high density of emission sources in these locations. The resulting haze may be carried by winds hundreds of kilometers from where it was generated, obscuring visibility even in remote wilderness areas. The acids formed accelerate the weathering of exposed stone, brick, concrete, glass, metal, and paint. For example, the calcite in limestone and marble reacts with water and sulfuric acid to form gypsum (calcium sulfate). The gypsum washes off stone with rain or, if eaves protect the stone, accumulates as a soot-darkened crust. Acid-induced weathering has obscured the details of elaborate carvings on medieval cathedrals, ancient Greek columns, and Mayan ruins at alarming rates.

Prevention Efforts

Discovery of the connection between sulfur emissions in continental Europe and lake acidification in Scandinavian countries ultimately led to the 1979 Convention on Long-Range Transboundary Air Pollution. This legally binding international agreement addresses air-pollution issues on a broad regional basis. Subsequent protocols to the convention deal specifically with sulfur emissions (1985 and 1994 protocols), NO_x emissions (1988 protocol), and acidification abatement (1999 protocol).

In the United States the Acidic Deposition Control Program, Title IV of the CAA amendments of 1990, directs the Environmental Protection Agency (EPA) to reduce the adverse effects of acid rain, specifically through a reduction in emissions of SO_2 and NO_x. The program sets an annual cap on SO_2 emissions from power plants and establishes allowable NO_x emission rates based on boiler type. Between 1990 and 2006, the program achieved a reduction of

SO_2 emissions by more than 6.3 million tons from 1990 levels. The program, in combination with other efforts to reduce emissions, also cut NO_x emission by roughly 3 million tons, making 2006 emissions less than half what would have been expected without the program.

The National Acid Precipitation Assessment Program coordinates interagency acid deposition monitoring and research and assesses the cost, benefits, and effectiveness of acid deposition control strategies. Acid deposition reduction schemes in the United States target large electric utilities, which as of 2006 were responsible for about 67 percent of the country's SO_2 and 19 percent of the NO_x emissions from anthropogenic sources. Utilities participate in a novel market-based emission allowance trading and banking system that permits great flexibility in controlling SO_2 emissions. For example, utilities may choose to remove sulfur from coal by cleaning it, to burn a cleaner fuel such as natural gas, or to install a gas desulfurization system to reduce emissions. They may also buy or sell emissions allowances. U.S. research efforts cost-shared between government and industry, such as the Clean Coal Power Initiative and similar programs before it, have developed technologies—for example, the catalytic conversion of NO_x to inert nitrogen—that can radically decrease emissions of acid gases from coal-fired power plants.

Between 1990 and 2006 annual atmospheric concentrations of SO_2 in the United States decreased by 53 percent, while nitrogen dioxide concentrations fell by 30 percent. Emissions of SO_2 dropped during this period by 38 percent; NO_x emissions declined 29 percent, with most of the decrease occurring after 1998. These reductions resulted in significant decreases in acid rain. Between 1985 and 2002, nitrate deposition declined in the New England states; however, in the western states, increasing oil and gas production and other factors caused nitrate deposition to rise. In the eastern states, sulfate concentrations in the air generally declined, affected regions decreased in size, and the magnitude of the highest concentrations dropped. During the periods from 1989 to 1991 and 2004 to 2006, sulfate deposition in the Northeast and the Midwest decreased by more than 30 percent. As a result, surface water quality improved.

Noreen D. Poor; updated by Karen N. Kähler

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See also: Air pollution; Automobile emissions; Clean Air Act and amendments; Coal-fired power plants; Convention on Long-Range Transboundary Air Pollution; Fish kills; London smog disaster; Nitrogen oxides; Power plants; Sudbury, Ontario, emissions; Sulfur oxides.

■ Acid mine drainage

Fields of Study: Biology, Life Sciences, Ecosystems; Elements, Substances, Chemicals, Compounds; Pollution, Emissions, Toxic Waste, Hazardous Materials; Ecology, Environment, Environmentalism.

Identification: The flow of acidified waters from mining operations and mine wastes

Acid mine drainage can pollute groundwater, surface water, and soils, producing adverse effects on plants and animals.

During mining, rock is broken and crushed, exposing fresh rock surfaces and minerals. Pyrite, or iron sulfide, is a common mineral encountered in metallic ore deposits. Rainwater, groundwater, or surface water that runs over the pyrite leaches out sulfur,

The Ducktown Historic District in Ducktown, Tennessee, in the southeastern United States. By Brian Stansberry (Own work)

plantings until the 1970's, when improved methods of fertilization and soil churning increased the plants' chances of survival. By the 1990's only about 405 hectares (1,000 acres) of land appeared to be bare, with large gullies and widely spaced trees. The restoration of the forest was not totally accepted by local residents, however, who believed that a small portion of the desert should be saved as an example of severe environmental degradation.

Rose Secrest

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■ Dust Bowl ecological disaster

Fields of Study: Agriculture; Climatology; Environmental Science; Environmental Studies; History; Hydrology; Meteorology;

The Event: Environmental disaster marked by huge dust storms in the southern region of the Great Plains of the United States

Date: 1930's

The Dust Bowl revealed the damage that mechanized agriculture could cause if not accompanied by a program of soil management.

Overview

Droughts periodically occur in the Great Plains of the United States. During such periods, winds pick up loose soil and create dust storms, especially during the spring months. Settlers reported numerous examples of this natural phenomenon during the nineteenth century. During the twentieth century, new agricultural practices and overgrazing by cattle sped soil erosion in the region. Tractors and other machines allowed farmers to plow larger areas for planting wheat. In the process, they destroyed the natural grasses, the root systems of which had stabilized the soil. Because the wheat replaced the grasses, most farmers remained unaware that they were contributing to a coming catastrophe.

In 1931 a severe drought struck the Great Plains; it centered on the Texas and Oklahoma panhandles, northeastern New Mexico, eastern Colorado, and southwestern Kansas. The wheat crop withered in the fields, and its root systems were no longer able to support the soil. As the drought continued, soil particles that normally clustered together within grass root networks separated into a fine dust. When the winds blew in early 1932, they lifted the dust into the air, marking the beginning of the environmental disaster that a newspaper reporter later dubbed the Dust Bowl.

Although their number and severity increased, dust storms remained an issue of local and regional concern for the first two years. However, as the drought continued into 1934, the storms grew so immense that they caused damage in areas far from the plains. A storm that emanated from Montana and Wyoming in May, 1934, deposited an estimated twelve million tons of dust on Chicago, Illinois. Ships that were some 480 kilometers (300 miles) offshore in the Atlantic Ocean reported that dust from the same storm landed on their decks. Incidents such as


A farmer's son sits on a sand dune near his home in Liberal, Kansas, during the 1930's. (Library of Congress)

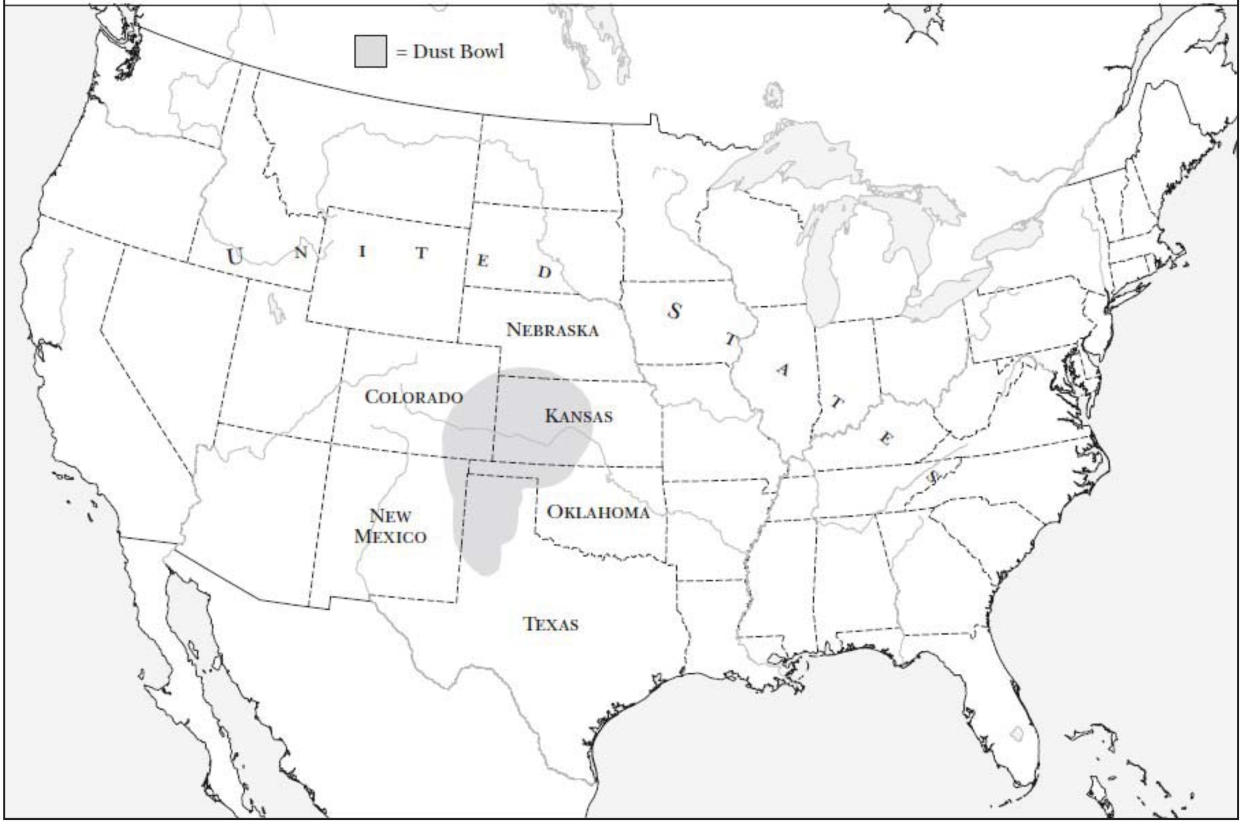
these provoked national concern over the growing crisis on the plains.

Scientists identified two types of dust storms: those caused by winds from the southwest and those resulting from air masses moving from the north. While no less damaging, the more frequent southwest storms tended to be milder than the terrifying northern storms, which came to be known as "black blizzards." Huge walls of dust, sometimes more than 1.6 kilometers (1 mile) high, rolled across the plains at 100 kilometers per hour (62 miles per hour) or faster, driving frightened birds before them. The sun would disappear, it would become as dark as night, and frightened people would huddle in their homes, their windows often taped shut. On occasion, people stranded outside during these severe storms suffocated. Some black blizzards lasted less than one hour; others reportedly continued for longer than three days.

Most historians argue that the Dust Bowl was one of the worst ecological disasters in the United States, one that could have been mitigated had farmers practiced soil conservation in the years before drought struck. Instead, farms were ruined, causing some 3.5 million people to abandon the land. Many of them moved into small towns on the plains, while others journeyed to California in search of opportunity. Cattle and wildlife choked to death. Human respiratory illnesses increased markedly during the Dust Bowl era, and a number of people died from an ailment known as dust pneumonia. Anecdotal evidence indicates that many people grew depressed as the dust storms continued year after year.

The mid-1930's marked the peak of the Dust Bowl, with seventy-two storms that reduced visibility to less than 1.6 kilometers (1 mile) reported in 1937. The return of the rain in the late 1930's eased the crisis, and by 1941 the disaster was over. However, by that time ecologists and farmers had begun to undertake soil conservation measures in response to the crisis. The U.S. government provided expertise and financial support for many of these efforts. Farmers practiced listing, a plowing process that makes deep furrows to capture the soil and prevent it from blowing. Alternating strips of planted wheat with dense, drought-resistant feed crops such as sorghum slowed erosion by blocking wind and retaining moisture, which prevented the soil from separating into dust. On lands not farmed, natural grasses were planted to prevent erosion. The government also sponsored the Shelterbelt Project, a program that used rows of trees to form windbreaks. Millions of trees were planted throughout the Great Plains, with more than 4,828 kilometers (3,000 miles) of shelterbelts created in Kansas alone.

Despite the experiences of the 1930's, once the drought ended many farmers returned to the farming practices that had damaged their fields. Soil conservation experts worried that the region would suffer a return of Dust Bowl conditions when the rains stopped. Their predictions came to pass in 1952, when another drought led to a series of dust storms, including several storms with wind gusts clocked at 129 kilometers (80 miles) per hour. That drought ended in 1957, but in accord with a twenty-year cycle, the region again faced a shortage of rainfall in the early 1970's. At that time some analysts confidently predicted that dust storms such as those seen in the 1930's were a thing of the past. They claimed that irrigation with aquifer water from deep wells would prevent soil erosion. However, shrewd



observers pointed out that the fate of the region was now tied to a resource, aquifer water, that would become increasingly precious in the coming years. The possibility that the Great Plains could again witness a devastating ecological catastrophe like that of the 1930's remains.

Thomas Clarkin

Further Reading

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