THE ATMOSPHERE AS AN INTERNATIONAL COMMON PROPERTY RESOURCE

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ABSTRACT

The impact of human activities on the atmosphere has become a global policy problem as scientific evidence has mounted on (a) the transboundary effects of acid deposition on lakes and forests, (b) a global warming trend attributable to a buildup of "greenhouse" gases, and (c) a depletion of the stratospheric ozone layer that can be linked to production of CFCs. These problems have been taken up by an extensive network of global and regional international institutions, in particular WMO, UNEP, ECE, and the ICSU. Extensive research on the condition of the atmosphere has been conducted since the IGY in 1957-8. As a common property resource, use of the atmosphere must be regulated internationally. Customary law has some applicability, but there is a need for further development of treaty law on emissions of specific air pollutants. Agreement on international regulations is hindered by differences of interest, concerns about equity, the limited ecological and technologial means of some countries, and the temptation to be a free rider. While some progress has been made, especially in increasing scientific knowledge of the threats to the atmosphere, states must do much more to regulate pollutants and landuse practice.

Introduction

The atmosphere is a thin, transparent layer of air enveloping the Earth, which sets it apart from other planets that are inhospitable to all forms of life. Not only is the atmosphere the source of oxygen, nitrogen, and other elements that are critical to the existence of the millions of species of plants and animals, but it also moderates the climate to which they have adapted and filters intense forms of solar radiation that would be destructive to life.

Mankind has used the atmosphere as a convenient medium for disposing of huge quantities of gaseous and particulate wastes, especially since the advent of the industrial revolution two centuries ago. These polluting activities have taken a heavy toll on the environment, but until recently the impact was usually localized around urban areas and industries or smelters that were major emitters or toxic pollutants. In recent years, however, scientific evidence has been mounting that pollution emissions and other human practices, such as large-scale forest clearing and land cultivation, are not only contaminating the atmosphere, but are also bringing about significant changes in the way it functions that could have significant consequences for the earth's inhabitants. Man has also been developing impressive techniques for intentionally modifying weather conditions toward both peaceful and hostile ends.(1)

This paper looks at human-induced changes to the atmosphere as a global policy problem. Even though it is an unconventional resource, the atmosphere has the attributes of a "global common property resource," as do the oceans, the seabed, outerspace, and the electromagnetic spectrum, and thus has been subject to a pattern overuse and misuse portrayed by Garrett Hardin (1968) in his famous essay on "the tragedy of the commons."(2) Rather than surveying all anthropogenic influences on the atmosphere, the focus is on three major phenomena that have recently alarmed scientists and policy makers: first, acid deposition associated with transboundary air pollution; second, warming of the lower atmosphere due to what is known as the "greenhouse effect;" and, third, the depletion of the stratospheric ozone layer. Some of the issues that arise in addressing these problems are pertinent to other human impacts on the atmosphere, including the widespread dispersal of radioactive pollutants from nuclear accidents, such as the Chernobyl disaster. They are also applicable to efforts modify weather intentionally, such as to increase precipitation, prevent hail, or reduce the intensity of hurricanes, which could have impacts far beyond the targeted geographical area.

The second part of the paper looks at the challenge of limiting further damage to the atmosphere. A growing number of international institutions have a concern with at least one of the major threats to the atmosphere. They, along with national governments and nongovernmental organizations have undertaken ambitious scientific programs to increase the base of knowledge on these problems by monitoring changes in the atmosphere and investigating the complex causes of them. Ultimately, however, international policies are needed that will manage the human impact on the atmosphere which are adaptable to common property resources. Several principles of international customary law have some applicability to the problem, especially those dealing with the responsibilities states have for activities under their jurisdiction that can damage the environment of other states. Nevertheless, it has been necessary to negotiate treaties that address the atmospheric problems more directly by setting forth rules on the emission of pollutants that apply to states. Finally, consideration is given to several economic and political factors that complicate the task of reaching an international consensus on measures that will effectively ameliorate the human impact on the atmosphere.

The Problem of Acid Deposition

Of the three major threats to the global atmosphere, acid deposition has had the most immediate and readily observable consequences. Acid deposition is a more appropriate term for what is commonly known as "acid rain" because the acidic moisture may reach the ground as rain, snow, mist, fog, frost, or dew. These forms of acid precipitation occur when oxides of sulphur or oxygen are emitted into the atmosphere where they undergo a chemical transformation in the presense of sunlight and water droplets to form dilute solutions of sulfuric and nitric acid that precipitate to the earth. Acid forming pollutants may also gravitate to the ground a dry form where they combine with surface moisture.(3)

While sulpher and nitrous oxides enter the atmosphere from natural sources such as volcanos, human activities account for 90 percent of the quantity of these substances in the air of the industrialized regions of the Northern Hemisphere (Barnaby 1988, p. 160). Sulfur oxides have been the predominant factor in acid precipitation since the early 20th century, but from 1960 the proportion attributable to nitrogen oxides has been increasing rapidly (WRI/IIED 1986, p. 169). The principal anthropogenic source of sulfur oxide in the atmosphere is the burning of fossil fuels containing sulfur, especially in coal fired power-generating plants, smelters, and heavy industry. The same sources are responsible for over half of the emissions of nitrogen oxides, but another significant source is the internal combustion engines of motorized vehicles (ReVelle and ReVelle 1988, 478).

Acid deposition is an important part of the problem of long-range transport of air pollution, known as LRTAP, which has arisen in industrialized regions with the advent of tall smokestacks designed to remedy localized pollution by dispersing contaminants over a larger area. Swedish soil scientist Svante Oden is credited with being the first to call attention to the spread of acid rain in the European region. Using data from a network of atmospheric monitoring systems in Western Europe begun by Sweden in 1952, Oden by 1968 was able to demonstrate a link between the acid precipitation thought to be responsible for the decline of fish populations in lakes throughout Scandinavia and the emission of large amounts of sulfur dioxide and nitrogen oxides in the United Kingdom and Central Europe (see O'Sullivan 1985, 14). Foreign sources currently account for approximately 90 percent of sulfur pollutants in Norway and Switzerland, more than 80 percent in Sweden and Austria, and more than 70 percent in the Netherlands (cited in O'Sullivan 1985, 18). Canada complains that the United States is responsible for at least half of the pollutants causing acid precipitation its Eastern provinces (Lewis and Davis 1986, 21).

Emissions of sulfur oxides in Europe rose by 50 percent between 1955 and 1970, which were reflected in a 2.5 percent average annual increase in sulfate concentrations in precipitation recorded at a network of 120 sites around the region (WRI/IIED 1986, p. 169). Since then emissions and atmospheric concentrations of sulfur have leveled off and even declined in parts of the region and improvements in air quality have been noted, especially where stringent controls on atmospheric pollution have been imposed. Likewise, concentrations of atmospheric nitrate doubled through much of Europe between the late 1950s and the early 1970s. During the

1970s, emissions from stationary sources were stable, but those from vehicles continued to increase. Nitric oxide emissions have been stable to lower since 1979, with the sharpest reductions occuring where catalytic converters are required on automobiles. Unfortunately, comparable long-term data on air pollution in North America is sparce by comparison to that for Europe. The only American site where records date back more 20 years is Hubbard Brook, New Hampshire (WRI/IIED 1987, 152).

Acidic precipitation is also being observed in industrialized regions of Third World countries, such as China, Brazil, Nigeria, and South Africa, but the consequences have generally been confined to areas near the sources of pollution and thus has not yet been a significant transboundary phenomenon. China is of particular concern, having passed the Soviet Union as the world's largest producer of coal, much of which is high in sulfur content. Precipitation in some regions of China has had an acid content that is as high as that recorded in the eastern United States, which has taken a heavy toll on Chinese forests especially in the southern provinces of Sichuan and Guizhow (Zhao and Sun 1986, 3; Li 1987, 7). China's plans to draw upon its huge reserves to double coal consumption by the year 2000 along with rapidly increasing vehicular traffic portends even more severe damage unless substantial investments are made in emission control (Brown and Flavin 1988, 12).

Acid deposition has many apparent consequences, some of which are still not adequately understood. Throughout Europe and in other industrialized regions, acid precipitation is causing noticeable damage to stone statues, monuments, and structures, including artifacts of earlier civilizations. It is also corroding metal surfaces, such as steel in railroad tracks and bridges. Pipes that carry acidic water are also subject to corrosion, exposing human population to lead and other toxic metals. Along with ozone, acid precipitation has been found to damage or retard the growth of agricultural crops. When absorbed by the soil, it leaches nutriants and unlocks chemical bonds releasing minerals that are toxic to plants (see McCormick 1985). But it is the apparent link between acid deposition and the disappearance of aquatic life and the devastation of forests over large areas of North America and Europe that has provoked the greatest concern.

The impact of acid rain on lakes is most pronounced where the bedrock is comprised of igneous or metamorphic rock as opposed to sedimentary rock that dissolves in water runoff, thus injecting minerals into lakes that neutralize acids. The most widespread damage to aquatic life in fresh-water lakes has taken place in eastern North America and Scandinavia. Canadian officials complain that 14,000 lakes in eastern Canada are acid dead as are 13 salmon-bearing rivers in Nova Scotia (Frances 1987, 11). In Sweden 15,000 lakes have been severely acidified by air pollution, including 1,800 which are virtually lifeless (see McCormick 1985). Recently, it has been confirmed that acid precipitation is also a primary factor in the death of marine life along the East coast of the United States (Shabecoff 1988, 1,9).

Damage to forests, or what is known as waldsterben ---the German term for "forest death," has recently become the most ominous environmental consequence of acid precipitation. The first signs of forest damage were observed on Western German white fir in the early 1970s. At the time, these signs were not considered extraordinary because isolated episodes of forest decline attributable to droughts, insects, and other natural causes had been observed in Europe for 250 years. By the end of the 1970s foresters realized that they were confronted with a broader and more complicated problem when an unfamiliar pattern of symptoms of forest death was observed in stands of Norway spruce and Scotch pine and eventually spread to eleven major species of conifers and broad-leafed species. Forest death has also occured over large areas of North America, but the symptoms differ from those observed in Europe and only conifers have been seriously affected thus far (see WRI/IIED 1986, 203-226).

The forest-death phenomenon spread dramatically during the early 1980s. Only 8 percent of West German forests were affected in 1982, but the figure shot up to 34 percent in 1983 and to 50 percent in 1984 (Hinrichsen 1986, 23). One fifth of the forests in 19 European countries were affected by 1986, with the Netherlands, Switzerland, and West Germany reporting damage to more than 50 percent of their forests (see Brown and Flavin 1988, 14-15). Recent figures indicate the forest death problem in West Germany is leveling off, but it continues to spread in most of Europe (see WRI/IIED, 1987, 156).

The causes of waldsterben is still a puzzle to scientists who have been sorting through the effects of scores of potential contributing factors. It is apparent that it is not the result of a single cause, such as acid precipation, but an entire syndrome of interacting factors. Furthermore, forest death seems to be caused by a different set of factors in Europe than in the North America. High levels of acid deposition are present in all afflicted regions. Damage is generally greatest at higher elevations that are frequently shrouded in fogs that have a high acid content. Other pollutants such as ozone also appear to adversely affect forests (ReVelle and ReVelle, 1988, 500-501). The problem of isolating the impact of pollutants is complicated by the tendency for dying trees in afflicted areas to succumb to natural secondary stress factors, such as insects, fungi, or severe climatic conditions---drought, wind, or cold---which healthy trees could be expected to ward off (WRI/IIED 1986, 208).

The Problem of Global Climate Change

The atmosphere is a major determinant of weather and climate both because it converts short-wave solar energy into longer, infrared waves that warm the surface air, but also because it functions like a greenhouse in retarding the radiation of heat from the earth. This heat would otherwise be lost to outer space and night-time temperatures would plunge dramatically. Paradoxically, oxygen and nitrogen, which together comprise 98 percent of the atmospheric gases, absorb very little solar radiation. Rather it is carbon dioxide, which naturally comprises only .03 percent of air, along with traces of several other "greenhouse" gases, that account for most of the warming of the lower atmosphere (Wagner 1978, 5-6). Abnormally cold periods such as the ice ages have been attributed to naturally occuring reductions of these greenhouse gases.

The heat absorbing qualities of atmospheric carbon dioxide were initially detected by nineteenth century European scientists, who went so far as to calculate the impact a doubling of carbon dioxide would have on surface air temperatures (Kellogg 1987, 115). Systematic data on atmospheric carbon dioxide dates back only to the late 1950s, when scientists began taking regular readings at Mauna Loa Observatory in Hawaii and at the South Pole in conjunction with the International Geophysical Year. Global networks of atmospheric and weather reporting stations on land and sea along with orbiting satellites now provide much more comprehensive data on current concentrations of greenhouse gases in the atmosphere and global climatic conditions. Long-term historical trends in the concentration of atmospheric gases have been plotted by sampling air locked in the polar ice caps.

There is now conclusive evidence that atmospheric concentrations of carbon dioxide (CO_2) have risen substantially over the past two centuries. CO_2 levels were in the range of 250-275 parts per million (ppm) prior to the industrial revolution (Kellogg 1987, 119). Levels of CO_2 recorded at Mauna Loa reached 316 ppm by 1958 and 345 by 1985, an increase over preindustrial levels of more than 25 percent (WRI/IIED 1986, 174-5). This increase can be attributed in large part to a ten-fold increase in the consumption of energy during the twentieth century, most of which was produced by burning fossil fuels in the industrialized countries (Koomanoff 1985, v-vi).

Increasing attention has been given lately to the impact that other greenhouse gases, such as nitrous oxide, ozone, and CFCs, may have on climate. Of particular concern is methane, which is released where bacteria decomposes plant material, as in the rumens of sheep and cattle. Atmospheric concentrations of methane have been growing an average of 1 percent a year over the past decade (Blake and Rowland 1988, 1129). If this increase continues, the impact of the greenhouse gases other than CO_2 on the global climate may be as much as that of CO_2 by the early 21st century. By 2030 the combined impact of the greenhouse gases may be the equivalent of a doubling of preindustrial levels of CO_2 (WRI/IIED 1986, 174).

It is more difficult to gauge the impact of increased atmospheric concentrations of greenhouse gases on climate because of naturally occuring variations in the weather. Moreover, the warming of the atmosphere may be delayed for a decade or more by the heat absorbing capacity of the oceans as well as of the land and its vegetation. The warming that has taken place since 1850 is believed to be on the order of one degree centigrade. The doubling of greenhouse gases projected for 2030 is forecast to cause a rise in average surface temperatures in the range from 1.5 to 4.5 degrees centigrade, a change that could be sudden rather than gradual (UNEP/WHO/ICSU 1985, 2; Broecker 1987, 123). By comparison, natural fluctuations are believed to have been no more than 1 or 2 degrees celcius over the past 10,000 years (UNEP undated, p. 5).

Predictions of the secondary consequences of the CO_2 buildup and global warming of this magnitude are more tentative. Agriculture operations in some areas, such as Scandinavia, may benefit directly from the CO_2 in the atmosphere or from longer growing seasons and increased humidity and rainfall (Ashuvud 1986, 52). Hotter and dryer conditions may seriously hinder agriculture in the temperate areas that have been highly productive, as in the United States. The projected 1.5 to 4.5 C degree increase in temperatures could cause sea levels to rise by 20 to 140 cm. due to thermal expansion and a more rapid melting of glacial ice in the polar regions and mid-latitude mountain ranges. A rise of more than a meter would cause flooding problems for coastal regions where many of the world's major cities are located. A more rapid melting of the polar ice caps, in particular the West Antarctic ice sheet, could raise water levels much more, but such a development is not believed to be very likely during the next century (ICSU/UNEP/WMO 1985, 2).

The Ozone Depletion Problem

While the greenhouse effect is a phenomenon confined primarily to the troposphere, the lowest level of the atmosphere that extends to an altitude of six miles, the problem of ozone depletion is taking place in the next level, the stratosphere, which extends upward to 30 miles above the earth's surface. In this zone a thin, fragile concentration of naturally occurring ozone, amounting to just a few parts per million of the atmosphere absorbs 99 percent of the incoming ultraviolet radiation from the sun. Two scientists reported in 1974 that families of industrially produced chemicals, in particular chlorofluorocarbons (CFCs), are linked to a diminishing of the stratospheric ozone layer (Molina and Rowland 1974). CFCs, which also contribute to the greenhouse effect, are highly stable molecules that drift slowly upward to the stratosphere where intense solar radiation breaks down the tight chemical bonds, releasing highly active chlorine atoms that destroy ozone molecules by gobbling up one of their three oxygen atoms.

CFCs were first produced in 1928 and since then have become a major industry. Under the better known trade name Freon, CFCs have been used extensively as coolants in refrigeration and air conditioning systems. They have also been used as the propellant in aerosol sprays, although this type of use has declined substantially after being made illegal in the United States in 1978, which at that time accounted for nearly one-third of aerosol use, as well as in Canada and Scandinavia (Crawford 1986, 927). Other applications include rigid foam packaging, flexible foam for furniture and automobile seats, dry-cleaning fluids, insulation, and solvents in the electronic industry. Halogens, which have also been linked to ozone depletion, are used widely in fire extinguishers. These substances are preferred for these uses because of their chemical stability, efficiency, low toxicity, and low cost of production.

Initial projections of a sizeable loss of ozone made during the late 1970s were revised downward in the early 1980s to the point of being almost inconsequential. The resulting sense of relief soon ended when it was reported that ozone levels had been dropping dramatically over Antarctica during the spring season, leaving what has become known as an "ozone hole." Low concentrations of ozone were first detected in this region more than two decades ago by the British Antarctic Survey. The phenomenon was initially attributed to the unique meteorological conditions of the region until the mid-1980s when October readings from British land stations as well as from the American Nimbus 7 satellite indicated a precipitous drop in annual ozone readings. By 1985 ozone concentrations were 40 percent below the average from 1957 to 1973, with most of the drop taking place since 1979. Furthermore, scientific evidence is now quite conclusive that CFCs were responsible for the decline (Rowland 1987, 54-56; Brasseur 1987, 40). There is also new evidence of a similar ozone hole in the Arctic region (Kerr 1988b, 1144-45).

Alarm over the Antarctic ozone hole prompted the United States National Aeronautics and Space Administration (NASA) in collaboration with other national and international agencies to create the Ozone Trends Panel for a stepped up monitoring of the ozone levels. A report released in March 1988 indicated that ozone concentrations over the Antarctic region had dropped to 50 percent of original levels and that the hole was persisting later into the year. It was also reported that ozone concentrations were dropping elsewhere, but inversely with distance from the poles. At the latitudes between New Orleans to Fairbanks, Alaska, the reduction ranged from 1.7 to 3.0 percent from 1969 to 1986.(4) Earlier in the year, a stir was caused by a report of an average worldwide drop of 5 percent in ozone levels from 1978 to 1986 based on satellite data, but questions have been raised about the instruments used in the measurements (Bowman 1988, 49)

The consequences of a continuing depletion of stratospheric ozone cannot be predicted with any degree of precision. Many species of plant and animal life may be damaged, if not killed off by the higher doses of ultraviolet radiation that would reach the biosphere. Aquatic species at the larvae stage may be especially vulnerable. It has been estimated that the increased radiation resulting from each one percent reduction in the ozone layer may lead to a 10 percent increase in human skin cancers (Kerr 1988a, 1491).

The Institutional Network

In Hardin's mythical village (see footnote 1), a town council may be needed to forumulate and implement a strategy for preventing overgrazing of the common pasture. In the case of the planet's atmosphere, the corresponding governing structures are a complex array of international governmental organizations (IGOs). Unlike a town council or a national government, however, most IGOs lack the authority to impose rules, but must induce the willing cooperation of sovereign states. Some IGOs address environmental problems exclusively; others as part of a wider mission. Some have a global, or universal, membership, others are limited in some way, most frequently to the states of a region. Possessing few financial resources of their own, international agencies commonly coordinate their activities with other IGOs and international non-governmental organizations (INGOs), as well as national governmental bodies and private associations.

Several specialized agencies of the United Nations system have missions related to the condition of the atmosphere. The three most centrally involved are the World Meteorological Organization (WMO), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and the United Nations Environment Programme (UNEP). WMO's primary function is to facilitate not only weather forecasting by providing current information on weather worldwide, but also to sponsor research on the causes of weather and long-term climate change. WMO has its origin in the International Meteorological Congress of 1853, which agreed to standardize reporting of weather conditions from sea-based stations. Coordination of weather reporting continued under the International Meteorology Organization, which was established in 1873. The organization was reconstituted and given its current name in 1951 (Davies 1972, 327; Cain 1983, 80). Founded in 1946, UNESCO's principal role in regard to the atmosphere has been to facilitate scientific research by linking scientific organizations throughout the world which have relevant expertise and by promoting major cooperative projects among them. The Inter-Governmental Oceanographic Commission (IOC) was established as off-shoot of UNESCO in 1960 to advance research on oceans, including their impact on the atmosphere.

Since its establishment in 1972 following the United Nations Conference on the Human Environment in Stockholm, UNEP has coordinated the diverse environmental initiatives of the other specialized agencies and promoted a holistic perspective on the global environment. Over the past decade UNEP's Coordinating Committee on the Ozone Layer (CCOL) has produced a series of reports on the condition of the ozone shield. UNEP has not limited its role to investigating problems, but has also sponsored international negotiations on regulations that will limit further degradation of the environment. The Nairobi based agency has been especially successful in stimulating national governments to institute environmental programs. It also enters into a number of joint projects with both IGOs and INGOs. UNEP has worked with the World Health Organization (WHO) on the impact that higher dosages of ultraviolet radition would have on rates of skin cancer and the International Civil Aviation Organizaion (ICAO) on the threat to the ozone layer posed by pollutants from aircraft, especially supersonic types. UNEP has a joint project with WMO and Food and Agricultural Organization (FAO) on the ramifications that a global warming trend may have for agriculture throughout the world.(5)

The more limited geographical ranges of the problem of acidic deposition and other forms of transboundary air pollutants have prompted regional responses, especially among the developed countries where the problem is most pronounced. During the 1970s the Organization for Economic Cooperation and Development (OECD), which is comprised of the Western industrialized countries (including Japan, Australia, and New Zealand), has sponsored research on the subject and adopted principles pertaining to transboundary pollution. The Final Act of the Conference on Security an Cooperation in Europe in Helsinki in 1975 listed the environment as one of a number of potential subjects for cooperation between East and West. Thus, the United Nations Economic Commission for Europe (ECE), as the only available organization that encompasses both Eastern and Western Europe and North America as well, was chosen to become the principal arena for treaty negotiations on long-range, transboundary air pollution among the developed countries (Tollan 1985, 616; see also Wetstone and Rosencranz, 1984). The Commission of the European Economic Community (EEC) has also become increasingly active in the environmental realm. It has adopted standards on air quality and transboundary pollution that are binding on the membership of the Community (see Burchi 1985). The Council of Mutual Economic Assistance (CMEA) plays a corresponding role in the Soviet bloc, but has not gone as far in addressing the problem of air pollution.

The International Council of Scientific Unions (ICSU) is the most notable of the many INGOs involved in global policy making on the atmosphere. Established in 1931 to encourage international scientific activity for the benefit of mankind, the ICSU is an umbrella organization comprised of scientific academies and research councils from 71 countries, as well as 20 international scientific unions (WRI/IIED 1987, 178). The ICSU has mobilizing numerous scientific research efforts on the natural systems of the planet and is frequently called upon to provide expertise that informs global policies, and even to co-sponsor environmental projects along with UNEP and other specialized agencies. Much of the scientific exploration coordinated by the ICSU is undertaken by the interdisciplinary committees it has organized, such as the Scientific Committee on Problems of the Environment (SCOPE), which investigates the general impact of humans on the natural environment (Caldwell 1984, 98). Other ICSU committees working on problems related to the atmosphere include the Scientific Committee on Ocean Research (SCOR), the Scientific Committee on Antarctic Reseach (SCAR), and the Committee on Climatic Change and the Ocean (CCCO). The International Institute of Applied Systems Analysis (IIASA), the International Federation of Institutes of Advanced Studies (IFIAS), the World Resources Institute (WRI), and the World Watch Institute are also prominent among the INGOs that either contribute scientific knowledge on atmosphere problems or disseminate information and mobilizing support for national and international policies that will address them.

Problems related to the atmosphere have also been taken up by many national organizations and agencies, including an unusually large number of federal agencies in the United States. The Environmental Protection Agency

(EPA) is involved in research and policy making on a wide range of environmental problems, including atmospheric pollutants. The Department of Energy (DOE), which at times has worked at cross purposes with EPA, is especially concerned with the relationship between the production of energy and the problems of climate change and acid precipitation. The National Aeronautics and Space Administration (NASA), through its Earth Systems Science project, monitors the interactions of the atmosphere, oceans, and terrestrial systems using both satellites and ground stations. Likewise, the National Center for Atmospheric Research (NCAR) is even more exclusively charged with research on the atmosphere, as is the National Oceanic and Atmospheric Administration (NOAA). The National Science Foundation (NSF) has sought funding for an initiative on Global Ecosystems that will support research aimed at illuminating the relationships between earth systems. The Office of Science and Technology Policy (OSTP) has undertaken a review of the wide ranging research taking place in the earth sciences (see Malone 1986). Outside of governmental bureaucracy, the National Academy of Sciences has encouraged support for a concerted effort among scientists to learn about earth systems and the human impact on them.

Expanding the Base of Scientific Knowledge

Rational decisions on environmental policies presuppose reliable and pertinent information on the magnitude of human activities and the consequences that follow from them. The village council in Hardin's story (see footnote 1) might make use of time-series data on the numbers of cattle that were grazed and the corresponding condition of the pasture, as it deliberates on how many cattle to allow on the commons. Weather records over the same period could be helpful in determining the degree to which the observed depletion of the grasses was caused by overgrazing as opposed to natural fluctuations in temperature and rainfall. Similarly, an effective international response to contemporary problems such as the greenhouse effect and ozone depletion requires knowledge of the complex dynamics of the atmosphere and interrelated systems, namely the oceans, biosphere, and glaciers and polar ice, as well as the impact of human activities on them.

Development of such a base of knowledge entails systematic monitoring of the condition of the atmosphere, oceans, and glaciers using standard procedures at locations throughout the world. The data collected can be entered into computer models that simuluate natural systems, which can be used to forecast future conditions and to gain insights into causes and consequences of observed changes. These endeavors have been facilitated by new generations of large, high-speed computers and state-of-the-art telecommunication networks. Nevertheless, global monitoring is a formidable undertaking in view of the sheer size of the planet, much of which is uninhabited, and the difficulties encountered in arranging for precise, standarized observations from countries of primative scientific means. Even more challenging is the task of understanding the dynamic and highly complex interaction between the sun and the Earth's natural system, and the impact of a wide variety of human activities on them.

IGOs and INGOs, as well as national institutions, have done much to provide the scientific knowledge upon which global policy on the atmosphere can be based. The first major international initiative aimed at understanding the planet's natural systems was the eighteen-month International Geophysical Year (IGY) of 1957-58, which was sponsored jointly by the WMO and ICSU. The project was timed to coincide with a period of unusually strong solar activity and the first launchings of orbitting satellites by the Soviet Union and United States. Scientists from 66 nations participated in the effort, using the latest innovations in instrumentation to learn more about the properties of space, the weather, the oceans, and the frigid zones (see Atwood 1959).

The ostensible success of the IGY encouraged further international scientific cooperation. The WMO, in partnership with the ICSU, initiated the World Weather Watch (WWW), which has grown into a world-wide network of reporting stations on land and sea that provides meteorological data daily to national weather services and other international atmospheric research programs (Davies 1972, 329). WMO and the ICSU also collaborate on the Global Environmental Research Programme (GARP), instituted in 1967, which investigates large-scale patterns of air circulation and the effects of the oceans, as well as human activities, on the global climate (Caldwell 1984, 94-5). The Background Air Pollution Monitoring Network (BAPMoN), another WMO program that was initiated in 1970 and is now jointly sponsored with UNEP, collects data on air pollutants at "baseline" stations located in isolated regions in 95 countries where the air is less polluted than in urban regions (UNEP 1987, 25). WMO and UNEP have also joined with the ICSU in sponsoring the World Climate Program (WCP), an outgrowth of the International Climate Conference held in 1979. A second major conference on the extent of global climate change as well as its causes and consequences was held in Villach, Austria, in 1985. The condition of the oceans is monitored by the Integrated Global Ocean Station System (IGOSS), a cooperative venture of WMO and UNESCO's IOC, using automated buoys that collect and transmit information on the relationship between the oceans and the atmosphere (Caldwell 1984, 241).

UNEP has considerably expanded and coordinated the environmental monitoring efforts of IGOs, INGOs, and national governments through its Worldwatch Program. A principal component of this program is the Global Environmental Monitoring System (GEMS), which surveys trends on numerous variables pertaining to climate, transboundary pollution, terrestial renewable national resources, and oceans, many of which have some bearing on the condition of the atmosphere. Thus far, as many as 142 nations and 30,000 scientists and technicians have particiated in at least one GEMS activity (UNEP 1987c, 25).

Mounting concern about the effects of human activities on the global environment prompted the ICSU, which three decades ago had sponsored the IGY, to launch another ambitious scientific effort called the International Geosphere-Biosphere Programme (IGBP) in 1986. Projected to be the biggest research project undertaken by organized science, IGBP would last for 10-20 years with the objective of accumulating knowledge on the total earth system, including the interactions between the atmosphere, hydrosphere, lithosphere, and ecosphere, as a way of understanding more fully the probable magnitude of human-induced changes over the next one hundred years (see Malone 1986). A complementary effort among social scientists called the Human Responses to Global Change Project (HRGCP) is being organized by the United Nations University (UNU), the International Social Science Council (ISSC), and the International Federation of Institutes of Advanced Study (IFIAS).

The Atmosphere as a Common Property Resource

Global monitoring and simulation models of the atmosphere do nothing in and of themselves to ameliorate the problems elaborated upon in the first part of the paper. International policy makers must face the more formidable challenge of instituting a management scheme that reduces human activities that are altering the atmosphere. The options available to them are limited by physical attributes of the atmosphere, which conform to the three basic criteria of a "common property resource" (see Wijkman 1982, 511). First, the resource is subject to "joint use," which implies that several users can not only derive benefits from it, but can also diminish its value to others. Second, it is not feasible to divide the resource into sections that could be assigned to individual users. Third, it is not practical to exclude unauthorized users from the resource (Oakerson 1986, 15-17).

The atmosphere is subject to joint use in that emissions of multiple polluters can be absorbed up to a point, beyond which the cumulative affects begin to seriously disrupt planetary ecosystems. Furthermore, while what is known as "air space" has, in a legal sense, been divided into sections that coincide with the boundaries of the states that can potentially develop the capacity to ward off encroachers, the gases that comprise air itself are continually circulating and intermingling and thus cannot be contained within boundaries. Finally, short of military occupation, it is not possible for states to physically prevent actors in other sovereign states from emitting wastes into the atmosphere that will drift across international borders or to undertake landuse projects that will have an impact on regional or global climatic patterns.

Several legal principles pertaining to ownership and user privileges have been applied to domains or resources that are beyond the territorial jurisdictions of states, such as the oceans and seabed, Antarctica and other uninhabited territories, the atmosphere, and outer space. The status of res nullius presumes that such a domain is not owned presently, but that all or part of it is subject to exclusive claims by states that will make use of it. Res communis also presumes a domain is currently unowned, but prohibits the staking of any exclusive claims in the future. All states are permitted to make use of the commons to the extent that they do not unduly interfere with the legitimate activities of others. A third alternative, res publica vests ownership with the community of states as a whole, which is entitled to establish rules regarding use of the domain by states or even to authorize use by a community enterprise. In the case of the oceans, the principle of the "freedom of the seas" incorporates the assumptions of res communis, while the contending "common heritage of man" and the establishment of an international public enterprise for mining the deep seabed are applications of res publica (see Christy and Scott 1965, 6-7). As with most international common property resources, the atmosphere has traditionally been governed by the res communis doctrine and states accordingly have taken for granted the right to use it as a sink for their pollutants.

While being more suitable for common property resources, the res communis arrangement is susceptible to the overuse and even permanent destruction of a resource, for the reasons that the pasture in Hardin's village is overgrazed (see footnote 1). In the case of the atmosphere, the "tragedy" results not from what is taken out of the resource domain, but what is put into it. Actors throughout the world have been permitted to use the atmosphere as a sink for pollutants rather than absorb the much higher costs of disposing of them in other ways. By their calculations, the immediate benefits from emitting pollutants into the atmosphere outweigh the harmful environmental consequences of these activities, which they will eventually share with the larger community. Likewise, forests have been cleared and grassland plowed up for immediate private or national gain with little concern for how these activities may accelerate global warming.

Several strategies are theoretical possibilities for preventing destructive overuse of a commonly used resource. In Hardin's analogy, a village council could retain the commons system, but set and enforce limits on the number of cattle the herdsmen could graze. Alternatively, the village council could discard the commons arrangement and divide the pasture into fenced plots assigned to individual herdsmen, who would then not only enjoy the profits but also absorb all of the environmental costs from overgrazing their portion of the pasture. Finally, the council could buy the cattle from the herdsmen and manage them as a community herd within environmental limits. The profits would be distributed to the villagers according to an agreed upon formula (see Soroos, 1988).

The only viable approach for alleviating the disruptive impact of human activities on the atmosphere is for regional or global groupings of states to agree upon international regulations that limit or prohibit the activities that are causing the conditions of concern to scientists. The alternative of partitioning the resource into private sections assigned to states would be impractical in the case of the atmosphere because of the continual movement of air across national boundaries. It would also not be feasible for an international institution to take control over all operations that pollute the atmosphere in view of the enormous number and diversity of polluting activities and the long-standing freedom that states have had to use the atmosphere at their whim.

Applicable Principles of International Customary Law

Several of customary norms of state behavior, which is the traditional source of international law, are applicable to the problem of regulating human activities that affect the atmosphere. International customary law does not originate in a written document but in the practice of a large number of states over a long period of time. However, interpretations of it are found in the writings of legal authorities, decisions of international tribunals, resolutions adopted by international bodies, and attempts to codify, most notably by the International Law Commission. It is generally considered to be bindings on all states.(6) This section briefly considers two sets of conflicting norms relevant to the problem of preserving the environment: first, the prerogatives of state sovereignty versus the responsibilities of states for damage beyond their borders and, second, the freedom to use common property and shared resources versus the mandate of equitable sharing.

The doctrine of state sovereignty, one of the cornerstones of the international legal order, recognizes the state as the supreme decision-making authority and enforcers of rules within its territory. In its purist, laissez-faire interpretation, sovereignty would imply a right of a state to permit polluting activities on its territory without regard to consequences beyond its borders, such as the occurrence of acid precipitation. Similarly, a state would be within its rights to undertake large-scale clearing of tropical forests despite warnings about the impact such operations would have planet's CO_2 balance. While sovereignty has generally not been viewed in such an absolute way, states traditionally have acknowledged few restrictions on what they permitted to take place within their borders even if significant damage to the environment is caused elsewhere (Springer 1983, 130).

There has been a growing realization, however, that states must assume some responsibility for the external consequences of what takes place within their jurisdiction or control. Widely referred to as the principle of "good neighborliness," this doctrine can be traced to the Roman law maxim of sic utere tuo ut alienum non laedas (use your own property so as not to injure that of another) (Schneider 1979, 142). The applicability of this principle to transboundary air pollution is illustrated by the celebrated Trail Smelter arbitration (1941) in which the United States complained that fumes from a smelter in British Columbia damaged orchards across the border in the state of Washington. A special international tribunal ruled in favor of the United States on grounds that "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 serious consequence or the injury is established by clear and convincing evidence..." (International Court of Justice 1949, 1905). Article 21 of the Declaration adopted at the Stockholm conference of 1972, is another frequently cited as an expression of the principle of good neighborliness.

> States have in accordance with the Charter of the UN and the principles of international law, the sovereign right to exploit their own resources pursuant to their own environmental policies, and the responsibility to ensure that activities within their jurisdiction or control do not cause damage to the environment of other States or of areas beyond the limits of national jurisdiction (UN Conference on the Human Environment 1972).

A state victimized by activities taking place in another state may invoke the principle of liability, arguing that harms to its territory perpetrated by foreign actors are an infringement upon its property rights. The responsible party may be called upon to pay compensation for the damages and, to the extent possible, to re-establish the conditions that would have existed had the incident not occurred. The Trail Smelter arbitration directed Canada to pay compensation to the United States for damages caused by the pollution originating in its territory. Likewise, the United States paid Japan $2 million in 1954 to compensate fishermen exposed to fallout from a nuclear test in the Pacific. Article 22 of the Stockholm Declaration of 1972 encourages states to "cooperate to further develop the international law regarding liability and compensation for the victims of pollution and other environmental damage caused by activities beyond their jurisdiction" (UN Conference on the Human Environment 1982). International thinking about the conditions under which liability can be claimed has been changing to the benefit of victims. The traditional presumption that liability must involve a wrongful behavior committed intentionally or out of negligence is giving way to the notion of strict liability, which does not assume these conditions, and even absolute liability, which does not even excuse a state for damaging resulting from an "act of god" in the case of operations that inherently risky and could have catastrophic results (see Weis 1978).

States are assuming a growing set of obligations to countries that might be adversely affected by projects that are being planned. They have a "duty to inform" other states of dangers or harms that may emanate from areas within their jurisdictions. Such information should be provided in a timely fashion with sufficient detail to allow the potential victims to minimize the resulting damage.(7) The Soviet Union's failure to promptly warn of he radiation hazard caused by the Chernobyl accident in 1986 is an apparent breach of this duty to inform, although in this case the threat was from an accident rather than a proposed project. The "duty to consult" suggests that states should go a step further and allow states that may be harmed by a project to express their concerns about it. Recommendation 70 adopted at the 1972 Stockholm conference suggests that this "duty to consult" applies to those whose activities may have appreciable effect on the climate beyond their borders (see Weeis 1982, 270). Consultations may occasionally persuade a state to abort a potentially harmful activity, especially if the environmental consequences had not been fully anticipated or there is a desire to minimize political conflict with states that oppose it. A further step would be to require the "prior approval" of potentially affected states. Aside from certain regional groupings, the community of states has been reluctant to recognize this more stringent requirement, which could become a major infringement of their sovereignty (Springer 1983, 146-52).

International customary law also offers some guidance on the use of resources that are shared by a group of states, such as river systems, aquifers, or radiowaves, or of areas that are beyond the jurisdiction of states, such as the oceans, the seabed, and outer space. It could be argued that air is a shared resource like water in that it flows across national boundaries, or that that it is like outer space in being an international commons. But here again, conflicting principles of customary law must be reconciled.

There is, on the one hand, a long-standing presumption that states have a right to make generally unrestricted use of shared or common resources. Under the "freedom of the sea doctrine," a basic tenet of international ocean law for centuries, states were allowed to help themselves to the bounty of the living resources as well as dump their wastes with few if any limitations (see Anand 1983). Similar freedoms applied to launching satellites into orbit in outer space and the use the airwaves for radio transmissions (see Soroos 1982). Likewise, it has been generally assumed that states could make use of the atmosphere to dispose of gaseous or particulate wastes.

These freedoms can be tolerated as long as the shared resources or international commons were vast enough that users did not interfere with one another. As the demands on these resources intensified to the point that serious conflicts arise between users, it becomes necessary to adopt rules that impinge on the traditional freedoms they have exercised. In the case of river systems where downstream states have been at the mercy of those upstream, arrangements have been worked out in accordance with the principle of "equity" or "equitable shares" (see Goldie 1985). Under this principle, down-wind states could similarly argue that the usefulness of an airshed is significantly compromised by the pollution emissions of up-wind countries (van Lier 1980, 114). Application of the equitable share principle is more complicated in the case of the atmosphere, however, because wind directions are variable whereas stream flows flow through down channels.

The tenets of international customary law that have been cited in this section are more applicable to the problem of acid deposition than they are to conditions of global warming and ozone depletion. The acid-related damage to buildings and statues and more importantly to fresh water lakes and forests can be readily observed, and to some extent quantified. Much is known about the sources of the pollutants and the chemical transformations that they undergo as they are transported by the atmosphere. Nevertheless, because pollutants from neighboring countries intermingle, it is difficult if not impossible to conclusively demonstrate that the pollutants from a specific country are responsible for specific damage in others. Moreover, the death of lakes and forests is a complex process that involves the interaction of many factors that are still not fully understood, making it all the more difficult to establish liability. Thus, the circumstances involving acid rain are not nearly as clear-cut as they were for the Trail Smelter arbitration. Climate change and depletion of the ozone layer are problems that are unlikely to have serious manifestations for decades, although several scientists attribute the hot, dry summer of 1988 in North America and elsewhere to the "greenhouse effect." Even if the consequences of these tendencies become more tangible, the link between these damages and pollution from specific countries will be even more tenuous that in the case of acidic precipitation.

Aside from these specific problems, it is unlikely that customary law will ever be an adequate basis for managing use of the atmosphere. The general nature of its principles are an advantage in that they can be applied flexibly to a wide range of situations, but their vagueness and lack of specificity also allows states to be evasive when it comes to taking the action that would be necessary to ameliorate the problems. Moreover, because it based on norms of behavior that have been observed over time, customary law tends to legitimize continuity of behavior, rather than being an instrument that can be used to mandate the rather abrupt changes in what is expected of states that may be needed to prevent substantial changes to the atmosphere.

The Atmosphere in International Treaty Law

In view of the limitations of customary law, more effort is being invested in negotiating treaties that spell out specific expectations of states that sign and ratify them. Nevertheless, international treaty law on the atmosphere is still at a primitive stage of development, especially compared to that which has been negotiated to protect the marine environment. Of 131 treaties that have been adopted to address international environmental problems, 30 focus primarily with pollution of the oceans or specific regional seas (UNEP 1985, 1987b). By contrast, only a few treaties address the condition of the atmosphere, and because they address narrowly defined problems, many of the human activities that are altering the global atmosphere and climate remain to be addressed.

Two treaties prohibit certain military uses of the atmosphere. The 1963 Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space and Under Water, which had 116 parties by 1987, was a response to mounting scientific evidence that radioactive fallout from extensive atmospheric testing by a few nuclear weapons states posed a serious danger to human health. Since then, the United States, Soviet Union, and United Kingdom have conducted their testing underground. However, France and China refused to accept the treaty and continued to conduct atmospheric tests in the atmosphere. The French discontinued their atmospheric testing program in 1974 in the face of vigorous protests from the states near their South Pacific test cite, as well as from more distant states such as Chile and Peru, which experienced sharp increases in radioactivity following test explosions. Australia and Zealand brought the issue before the International Court of Justice, but the case became moot when the French announced an end to their atmospheric testing program. China has also ceased testing nuclear explosives in the atmosphere.

The impact of warfare on the environment became a divisive issue at the Stockholm Conference in 1972, when the host country sharply criticized the United States for committing "ecocide"---the deliberate destruction or alteration of an environment as a military tactic---in fighting the Vietnam War. The Convention on the Prohibition of Military or Any Other Hostile Use of Environmental Modification Techniques was signed four years later and by 1987 had 43 ratifiers, including the United States and the Soviet Union. The convention prohibits the hostile use of a wide range of environmental modification techniques against other parties including those that would alter the atmosphere, such cloud-seeding operations. Allegations of violations are to be directed to the Security Council if substantiated by a Consultative Committee of Experts. A significant limitation of the convention is its failure to address environmental damage that is merely an unintended side effect of a military operation, such as the "nuclear winter" phenomenon that it is feared would result from an all-out nuclear war.(8) Nor does the convention address weather modification projects undertaken for expressly peaceful purposes.

Negotiations taking place in the United Nations Economic Commission for Europe (ECE) led in 1979 to the adoption of the Convention on Long-Range Transboundary Air Pollution, which called upon the parties "to limit and as far as possible, gradually reduce and prevent air pollution," including that of long-range variety. The convention is essentially a declaration of general objectives and a call for international cooperation in monitoring pollution levels and devising strategies for reducing emissions. It obligates no abatement methods, nor does not it mandate any specific reductions in emissions. Moreover, the convention is regional in scope, being limited to the membership of the ECE. The 27 parties to the convention do, however, account for two-thirds of the significant forms of anthropogenic atmospheric pollution (Sand 1987, 28).

The alarming spread of the forest death syndrome in central Europe during the early 1980s prompted efforts to put teeth into the 1979 ECE convention. With West Germany---one of the states most resistant to a strong treaty just a few year previously---playing an instrumental role, a protocol was added in 1985 that obligates participating states to reduce total national emissions or transboundary fluxes of sulphur 30 percent below their 1980 levels by 1993. The protocol was initially signed by 21 countries, which comprise what is known as the "30 per cent Club." Noting scientific uncertainty, the United States, United Kingdom, and Poland have not yet accepted the protocol. Ten states were already in compliance with the protocol by 1986; five of which are committed to cutting sulfur emissions by 50 percent of 1980 levels by the mid-1990s; four others have set an even higher goal of a two-thirds reduction. Negotiations taking place on a parallel protocol on emissions of nitrogen oxides in 1988 were not successful, in part because of the high cost of curbing emissions from motorized vehicles and the reluctance of states that already had stringent controls to make further percentage reductions. Another consideration is the beneficial effects that additional nitrogen in the soil may have on vegetation (Dilworth 1988).

UNEP has been engineering a parallel response to the ozone depletion problem, but on a global scale. The Convention for the Protection of the Ozone Layer, adopted in Vienna in 1985, parallels the 1979 ECE convention in calling for an international research effort on the severity of the problem and its causes and for unspecified strategies for reducing ozone-attacking emissions (see Sand 1985). Two years later, a much stronger agreement was negotiated in Montreal in the face of compelling new evidence about the growth of the "ozone hole" over Antarctica. The Montreal agreement would almost immediately freeze production of CFCs and halons at 1986 levels, followed by a reduction of 30 percent by 1993 and an additional 20 percent by 1998. Trade in CFCs or halons with nonparty states is prohibited, but rules remain to be established on tr ade in products that contain or were produced with these substances. Less developed countries are given an additional ten years to comply in view of their development plans and much lower level of CFC production and consumption. The convention comes into effect upon ratification by 11 states that account for at least two-thirds of world CFC production (UNEP 1987a, 1-2). The United States Senate promptly ratified the treaty by a vote of 83-0.

These few treaties are only the first steps toward limiting or preventing further adverse changes to the atmosphere and climate. Thus far, the most significant progress has been made in setting goals for reductions of transboundary air pollution responsible for acidic pollution in the European region and the global emissions of CFCs and halons that are attacking the stratospheric ozone layer. Nevertheless, some environmental NGOs have been critical of these targets for not going far enough. Representatives of 22 European groups meeting in Lida, Sweden, in September 1987 called for a 90 percent reduction in sulphur emissions in the region (Agren 1987, 16). NGOs have also advocated much sharper reductions in nitrous oxide emissions and production of CFCs than those incorporated into international conventions. By one calculation, stratospheric chlorine levels, under terms of the 1987 Montreal agreement, would double before leveling off by the middle of the next century, at which time there would be a 7 percent loss of the ozone layer and a 15 percent increase in harmful radiation (Goldstein 1988, 7).

While much is being done internationally to monitor the impact of human activities on the global climate, negotiations have not begun on rules that would limit the emission of carbon dioxide and other greenhouse gases into the atmosphere. Likewise, nothing has been done to regulate other causes of climate change, such as large-scale forest clearing, cultivation of grass lands, and rerouting of river systems. UNEP has, however, set 1995 as a target date for an "agreement on appropriate and timely measures" to deal with climate change (UNEP 1988).

The conventions on transboundary air pollution and protection of the ozone layer are promising precedents for additional international regulations that will be needed. They are notable for establishing goals for a reduction of specified types of pollutants by a specified date, and thus are examples of conduct-oriented, as opposed to result-oriented, policies. The Montreal convention on the ozone layer is also significant for demonstrating a willingness of states to make economic sacrifices in response to less than conclusive warnings of scientists of a problem that as yet has few tangible manifestations. It is also encouraging that Du Pont Chemical Company, the world's leading producer of CFCs, has announced a phase out of its production of them by the year 2000 in favor of developing environmentally benign substitutes (Goldstein 1988). Given the delayed impact of many atmospheric pollutants on the environment, it is important that additional steps such as these be taken to avert problems long before severe symptoms can be observed.

The Politics of Managing the Atmosphere

Sovereign states have had considerable difficulty in agreeing upon strategies for limiting the impact of their activities on the atmosphere. While across-the-board reductions, which have recently been written into several treaties, have the virtues of simplicity and consistency of standards, questions of equity inevitably arise. For example, should states that have a historically low level of pollution emissions be expected to achieve the same percentage reduction as those that have been heavy polluters? Thus, despite being a heavy net importer of acid-forming, transbounary air pollutants, Norway has resisted making a commitment to an international agreement specifying a 30 percent reduction in nitrogen oxides in view of its almost complete reliance on hydroelectric power and consequently low level of NOx emissions (Dillworth 1988). Less developed states, which have a history of low pollution emissions, may argue that "it's now our turn to pollute" in order to industrialize and achieve a standard of living closer to those being enjoyed in the highly developed countries.

A second question of equity arises in regard to states that have previously taken steps to control emissions. Should they be expected to achieve the same future reductions as less environmentally responsible states that have yet to take any action to address the problem. In failing to agree to a new protocol on nitrogen oxide emissions, the United States argued that it was only fair that it should be compensated for the substantial reductions it had achieved as a result of being a pioneer in requiring catalytic converters on automobiles.

Poorer countries, including those that perceive a need for preserving the atmosphere, may simply lack the financial resources and the technologies necessary to comply with international standards, or consider the costs to be too heavy a burden to absorb given what appear to be more pressing priorities. Thus, Poland and several of its Eastern European neighbors, which are heavy recipients of transboundary pollutants and thus would benefit from stronger international regulations, have been unable to make a reciprocating commitment to reduce their own emissions substantially for lack of sufficient hard currencies to import pollution abatement technologies (Rosencrancz 1986, 47-48).

Equity and economic considerations are not the only reasons why some states have not seen it in their interests to agree to percentage reductions, or any other type of restriction on polluting activities. Among the least cooperative states on the acid deposition problem are up-wind states in an airshed, such as the United Kingdom and the United States, which contribute more to the problem on other countries than they are the victims of pollution originating elsewhere (Rosencranz 1986, 48-49). In the case of the greenhouse effect, some states may perceive that they have little to lose or may even be net gainers from a global warming, and thus have less incentive to contribute to a global solution to the problem. States without large coastal populations will not have to cope with a rise in sea levels; in some areas agriculture may benefit from a longer growing season or increased rain (Kellogg 1987, 125). Finally, some states elect to play the free-rider role if they perceive that the severity of the atmospheric problems are being ameliorated sufficiently by the unilateral restrain of others. The unilateral decision of the United States in 1978 to ban the use of CFCs in most consumer goods perhaps lessened the sense of urgency for similar actions in other countries (Ember et al 1986, 49).

States that are persistent holdouts on international regulations on air pollution can undermine the willingness of other states to fulfill the commitments they have made. The international community has little leverage for bringing sovereign states into the fold. Political pressure such as that brought to bear on the United States by Canadian leaders may have some effect if it is perceived that a continuing failure to live up to international norms on air pollution will cause considerable discord in otherwise friendly and constructive relations between states. The economic incentives for certain polluting activities can be reduced by trade embargoes in polluting substances or the products created with them. For example, the United States, Soviet Union, and China, with 90 percent of known coal reserves, might consider curtailing exports of coal to countries that do not responsibly control emissions (Rose et al 1984, 56). Additional pressure could be placed on deviant states by farther reaching sanctions, a model being a United States law dictating that states violating international rules pertaining to the conservation of whales and other marine mammals lose 50 percent of the fishing rights they have previously enjoyed in the American 200-mile exclusive fishery zone.

States that lack the economic resources to comply with international standards must be dealt with in other ways. To bring them into a treaty framework, it may be necessary to grant them certain concessions. The Montreal protocol on the ozone problem allows developing states a ten-year grace period for accomplishing CFC reductions and specifies that they are to granted access to substitutes for the CFCs and halons causing the problem. Even then, richer victims of the pollution may have no other recourse but to assume a disproportionate share of the cost of reducing emissions, such as by subsidizing the transfer of abatement technologies. In making decisions on loans, international lending agencies, including the World Bank, have increasingly been taking environmental impacts into account, although not to the degree to which environmentally oriented NGOSs would have preferred. Offers of debt relief can also be used as leverage for environmentally responsible projects, a strategy that has aleady been financed on a small scale by NGOs.

Assessment and Prospects

The three atmospheric problems highlighted in this paper---acid deposition, global warming, and depletion of the ozone layer--are recent additions to the environmental agenda of the world community, and it is only in the last few years that the seriousness and magnitude of these problems has become apparent. Only the acid deposition problem has readily observable manifestations that demonstrate the need for a prompt international policy response. Global warming and ozone depletion would seem to be more serious threats to the well-being of mankind, but it will be decades before there will be significant tangible consequences. However, because of the considerable lag between the release of the pollutants and their effects, preventive measures must be undertaken in response to the warnings of the scientific community, which after earlier disagreements is becoming increasingly unified in its assessment of the severity of the greenhouse and ozone problems. Nevertheless, it is tempting for governments besieged with a multitude of more immediate problems to procrastinate on confronting these future environmental problems, which they can at least hope will not be as serious as was originally feared.

In view of these ominous possibilities resulting from human use of the skies as a sink for pollutants, it is imperative that the atmosphere be managed as a global common property resource, as has been done for the oceans and outer space. The problems are too complex and too large geographically to be treated simply as incidents of transboundary damage that can be resolved by general principles of international customary law, such as state responsibility, strict liability, good neighborliness, and the duty to inform. Internationally agreed upon standards are needed that pertain to emissions of the polluting substances which are of particular concern and, in the case of global warming, the other practices that compound the problem, such as large-scale clearing of tropical forests. The 1985 ECE protocol calling for reductions in emissions of sulphur dioxide and the 1987 Montreal Convention that mandates similar reductions in the manufacture of CFCs and halons are promising examples of the types of international regulations that are needed to avert these problems, but it appears they do not go far enough in view of new scientific evidence that the problems are more severe than had been believed previously.

The global warming problem will be especially challenging to address not only because the consequences are difficult to anticipate but also, more significantly, because a major reduction in emissions of CO_2 will require basic changes in the energy policies of all states. Nuclear power has not proven to be a suitable substitute for fossil fuels, as was once hoped. Thus, conservation may be the most promising strategy for reducing CO_2 emissions. There are limits, however, to what can be achieved without major sacrifices, especially in view of the continuing rapid growth in the world's population and the ambitions of Third World countries to industrialize and achieve the energy-intensive life styles of "modern" societies. It will also be difficult to persuade states that are desperately in need of import revenue and agricultural land to forgo the harvesting or clearing of tropical forests for the benefit of the world as a whole. The question also remains as to whether the problem has already reached the point that even major sacrifices would have only a marginal impact in retarding climate changes. If so, there may be no alternative but to invest heavily in strategies for anticipating and adapting to the inevitable climate changes.

Footnotes

1. Stephen H. Schneider (1976) was one of the first to call attention to the relationship between human activities and the atmosphere. See also Schneider and Londer (1984) for a more recent discussion of this subject.

2. In his essay, Hardin tells the story of a mythical English village in which the resident herdsmen keep adding privately owned cattle to a commonly owned pasture to the point of its destruction, figuring that as individuals they would personally gain more from each additional head of cattle than lose from their share of the resulting increase in the cost of overgrazing.

3. For further information on the phenomenon of acid deposition, see Likens et al (1979) and ReVelle and ReVelle, 1988, 493-99.

4. This report is summarized by Kerr (1988a, 1490).

5. For a more detailed description of the United Nations institutional network as it pertains to atmospheric and environmental problems, see Cain (1983) and Caldwell (1984, 87-100).

6. For a concise description of customary law and other sources of international law, see Akehurst (1982, 1-42). See also Nardin (1983).

7. The duty to inform is included in the Principles Concerning Transfrontier Pollution adopted by the OECD in 1974.

8. For a recent, non-technical collection of articles on the potential environmental implications of nuclear war, see the July 1988 issue of Environment.

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