MANAGING THE ATMOSPHERE AS A GLOBAL COMMONS

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INTRODUCTION

The tendency for shared resources, or what have become known as commons, to be degraded by overuse and misuse is a timeless problem of human societies that has been noted by scholars as early as Aristotle, who opined that "what is common to the greatest number has the least care bestowed upon it. Everybody thinks chiefly of his own, hardly at all of the common interest." (Quoted in Ostrom, 1990, p. 2). While Aristotle didn't have the atmosphere in mind--it had not been discovered by his time--his observation is now as applicable to the atmosphere as to any other planetary resource. Humanity has long used the atmosphere as a sink for many of its wastes with little awareness and concern for the ways it is being altered and degraded. Once believed to be vast enough to accommodate all human assaults, only in recent decades has it become apparent how limited the capacity of the atmosphere is for absorbing, dispersing, and disposing of anthropogenic pollutants without undergoing fundamental changes that will severely impact the Earth system, in particular the biosphere.

The problem of overuse of commons is often associated with the writings of biologist Garrett Hardin, especially his seminal article "The Tragedy of the Commons" (G. Hardin, 1968). Hardin explains the all too frequent fate of commons by drawing upon a parable, told in the nineteenth century by a little known Oxford professor named William Forster Lloyd (1833, reprinted 1968), in which the residents of a mythical old English village overuse a common pasture to its destruction. The "tragedy" occurs when the residents persist in adding privately owned cattle to increase their personal profit, even to the point that their aggregate herd exceeds significantly the number of cattle the pasture can sustain and nourish. The grass is consumed or trampled to the point that the pasture can no longer support even a much smaller herd. Unfortunately, the realization that the pasture is being severely degraded does not dissuade the villagers from adding more and more cattle, as they anticipate that whatever restraint they exercise individually for the good of the community will be more than compensated for by the excesses of the less scrupulous among them.

Numerous examples could be cited of commons that have been degraded or destroyed by a syndrome of overuse paralleling Hardin's story of the village pasture. The collapses of many of the once bountiful ocean fisheries due to overharvesting, such as cod in the northwest Atlantic and Alaska pollack in the Bering Sea, have the elements of Hardin's story (see Webber, 1995). Fishers have sought to maximize their short-term catch of a limited resource in the belief that whatever fish didn't end up in their own nets would be caught by somebody else. Hardin (1993) sees human population growth as an unfolding "tragedy" that is depleting the die back when their numbers exceed the carrying capacity of their habitats. A "tragedy of the atmosphere" has also been unfolding as the cumulative burden of pollutants emitted into it by human activities causes critical changes in its chemical composition, such as the thinning of the stratospheric ozone layer and increases in greenhouse gases far beyond naturally occurring concentrations.

Such "tragedies" are not inevitable, even when the resource being used is limited, as Hardin acknowledges in entitling a later article "The Tragedy of the *Unmanaged* Commons" (G. Hardin, 1991). The challenge for a community having a commons is to devise a management scheme that restrains use of its resource to a level that does not exceed its natural carrying capacity. While limits on the exploitation of a resource may be imposed upon users by the governments having jurisdiction over a commons, it is also not uncommon for a community of users to take collective action among themselves to preserve the resource upon which they depend (Ostrom 1990). Such arrangements, however, are most common and effective in relatively small, cohesive communities in which strong social pressure can discourage environmentally irresponsible behavior. There are, however, instances of the successful management of international commons, an example of which is the regulatory scheme for the electromagnetic spectrum that has been established and revised at the World Administrative Radio Conferences of the International Telecommunications Union, which is designed to minimize interference between competing users from different countries (see Soroos, 1982). Managing use of the atmosphere is a global commons poses much more complicated challenges for the international community.

WHAT IS A COMMONS?

A <u>commons</u> has three defining characteristics. First, it is a domain or collectivity of resources. In the mythical English village, the pasture is the resource domain, which contains grass that can be consumed by cattle. Second, the resource domain is available to multiple actors who use it for their individual benefit. In the English village, numerous households derive personal benefits from grazing cattle their privately owned cattle on the pasture. Third, the resources of the commons are finite and subtractive in that there is a limit to the amount that can be consumed, and what is appropriated by one actor is not available to others. It is assumed that the village pasture contains a certain amount of grass, and each clump eaten by one household's cow is not available to the cattle of others.

This conception of a commons makes a distinction between a <u>resource domain</u>, or what Elinor Ostrom (1990, p. 30) refers to as "resource system," and the <u>resource units</u> that comprise the domain. A commons is the more encompassing resource domain, such as the pasture in Hardin's parable, a forest, or a fish stock. The users help themselves to a portion of the stream or pool of resource units for their individual gain, such as the grass their cows eat in the pasture, the trees they cut down from a forest, or the fish they catch from an ocean fishery (Oakerson, 1992, p. 42). A land-fill is a resource domain, locations in it are the resource units. Similarly, the geosynchronous orbital arc 36,000 kilometers above the equator is a resource domain, whereas specific locations in the arc where satellites might be positioned are the resource units.

Characteristics of Resources

In a generic sense, a resource is something that is useful to humans. It may either be present in nature or be produced by humans. Natural resources that are used as commons are of many types, which have implications for how they may be used or managed. Resources are usually thought of as being physical substances that under normal conditions are in the form of a solid, such as coal or minerals; a liquid, such as petroleum or water; or a gas, such as helium or natural gas. Resources may be stationary, such as coal and forests, or mobile and thus fugitive, such as whales. Some resources are living such as fish, grass, and trees, while other others are inanimate, such as hard rock minerals.

It is often assumed that the use of natural resources invariably involves taking something out of the environment. Coal is extracted from the ground, trees are removed from a forest; fish are harvested from the oceans, and water is diverted from rivers. Alternatively, a resource may be something into which humans put things. A municipal land-fill is a resource into which people put their garbage. Likewise, the rivers and oceans are used as media for disposing of a wide variety of waste substances, commonly referred to as pollutants. The geosynchronous orbit is an important resource in outer space that is highly useful as a set of "parking places" for communication and weather satellites.

The residents of the mythical English village used the common pasture exclusively for the grazing of cattle. Some commons, however, are subjected to multiple uses, which, if they are conflicting, can greatly complicate the task of managing them. For example, a publicly owned forest plot may be a source of wood for the lumber industry, a provider of nuts and berries for indigenous peoples, a repository of genetic material for biotechnology companies, and a sink for carbon dioxide for the world community. The oceans have been used as a medium for navigation, a source of fish, and a sink for many types of pollutants. Cutting a forest precludes other uses of it; marine pollution contaminates ocean fisheries rendering the catch unfit for human consumption.

Use and Ownership

A commons is a resource domain that has multiple users who appropriate its resource units for individual profit. The community of users for resources can be large or small, which has implications both for the likelihood of a "tragedy" occurring from overuse and how such an outcome can be avoided. Use of a limited-access commons is restricted to a specified group of actors, while all others are excluded. For example, in the English village, it might be assumed that the privilege of grazing cattle on the common pasture would be limited to the permanent residents, with outsiders being prevented from adding their cattle. Other commons are open-access in the sense of being available to any actor who desires to make use of them, which has traditionally been the case with fishing on the high seas beyond the territorial jurisdiction of any state. Commons may be left as open-access because they are vast in relation to the use of them or because it is technically difficult or economically too costly to exclude other determined users (Oakerson, 1992, pp. 44-45). Resource domains that have these qualities are referred to as common pool resources (Ostrom, 1990, p. 30).

Contrary to widespread belief, categorizing a resource domain as a commons does not necessarily imply a presumption about who owns it. A commons could be owned by a community of actors, and thus be what is known as common property, or in effect the private property of the community. Such common property may have been given to the community or purchased by them, or it may have been created by the members merging their individually owned parts to create a larger and more useful resource. Alternatively, it may simply be considered common property by tradition or declared as such. The community of owners may decide to handle the resource domain as a limited-access commons by excluding outsiders, if they can, or open it up to use by all who desire to use it for their (Bromley, 1991, p. 29). Certain globally owned common resource domains, in particular the seabed and the moon, have been declared the "common heritage of mankind." Resources falling under the common heritage designation, however, are not necessarily treated as commons in that exploitation of the resource units by individual parties may be sharply curtailed, if not completely prohibited, to ensure that the resource is used for the benefit of all states, including those that lack the means to exploit them (Birnie, 1992, p. 121).

A second possibility is that a resource system belongs to a certain party either within or outside the community, who permits others to use it as a commons. Thus, the pasture in Hardin's village could be the property of a wealthy absentee landowner, who currently has no use for it and is benevolent or disinterested enough to allow the villagers to graze their cattle on it. Similarly, some countries permit fishing vessels from foreign countries to operate within the confines of their 200-mile exclusive economic zones, in particular when their own fishing industry has not been able to take full advantage of the calculated "total allowable catch."

Finally, a resource domain may have no recognized owner, as is the case with the high seas and the electromagnetic spectrum. Unowned domains are normally not considered a commons unless it is understood that they may not be claimed in part or in whole by any individual actor, as was traditionally done by explorers who discovered new lands. Such resources fall under the legal designation of res communis. This classification does not, however, preclude the possibility of the resource units derived from the commons becoming the property of whoever harvests them. Thus, while no nation may claim ownership over a high seas fishery categorized as res communis, and thus the exclusive right to harvest it, individual fish become the private property of whoever catches them. Similarly, a tree cut for lumber in a public forest becomes the property of whoever cuts it. These previously unowned resource units that can be appropriated from a commons by individual actors fall under the ownership concept of res nullius.

Subtractivity and Finiteness

Multiple actors may make use of a commons, but the resource units are subtractive in the sense that those that are appropriated by one actor are not available to the others. For example, a clump of grass that is eaten by a cow of one of the residents of Hardin's village is not available to the cattle of others. Furthermore, the cumulative effect of the consumption of resource units may eventually diminish the capacity of the resource domain to produce units, as when overfishing reduces the stock that is available for reproduction (Oakerson, 1992, p. 44).

The attribute of being subtractive distinguishes commons from a public good, as conceived by Mancur Olson (1965). Public goods can sustain "joint use," which means that consumption by one actor is not subtracted from, or does not diminish, what is available to other potential users. A television news report is a public good in that it can be made available to an unlimited number of individual viewers without being lessened in value. A second condition of a public good is the impossibility of excluding users, which may or may not be the case with commons (R. Hardin, 1982, p. 17).

Resource domains are also generally not considered commons unless there is an ultimate limit to the amount of use they can sustain without being significantly depleted or altered. The number of cattle that could be nourished sustainable on the pasture is limited, as is the amount fish that can be harvested without reducing the capacity of a fish stock to regenerate itself. If no such natural limits exist, subtractivity and the ultimate depletion of the resource never become reasons for concern and there will be no need to conserve the resource. All actors can help themselves to resource units as they like without lessening in any significant way the amount that others can consume, even though any specific resource unit can not be consumed by more than one of them. Certain resources, such as the ocean's fisheries, once seemed boundless in comparison to the amount of fish harvested, but with time use increases and eventually reaches and exceeds the amount of consumption that can be sustained. As this point approaches, subtractivity becomes an important consideration for the users who find themselves competing for the increasingly scarce resource units.

THE ATMOSPHERE AS A COMMONS

The atmosphere is a natural resource domain that is not simply useful, but is essential, to human life and the existence of most other species. As a composite of gases known as air, the atmosphere has physical mass. The air comprising the atmosphere moves over the surface of the earth in ever changing directions and velocities, and thus could be considered a fugitive resource. A specific volume of air that is not used at one time and place drifts away, while its place is immediately taken by another volume of air. Because air is a fluid, undifferentiated mass, its resource units are not discrete objects, such as a tree in a forest or a fish in the ocean. In this respect, air is similar to the waters of the oceans. Thus, resource units of air are of no naturally occurring size, nor can they be distinguished from one another.

Uses of the Atmosphere

Human beings use air and the atmosphere in many ways. Some uses extract gases from the air, such as oxygen in the acts of breathing or burning fossil fuels. Human consumption of atmospheric gases is minuscule compared to the available supply, thus there is no danger of the resource being depleted. Other uses entail putting substances into the atmosphere to dispose of them, or in other words the emitting of pollutants. It was once assumed that the atmosphere also had a boundless capacity for dispersing pollutants to harmless concentrations, but in recent decades it has become all too apparent that there are limits to the quantity of pollutants that can absorbed without serious environmental consequences. Human communities also make use of the atmosphere by taking advantage of its climate, for example in agriculture. For the most part, this is done passively with no impact on climate. However, experiments have been conducted with techniques that would alter weather in ways that serve agricultural or military purposes.

The atmosphere has generally been treated an open-access resource. To deny people the use of the atmosphere for respiration, assuming it was possible, would be tantamount to refusing them the right to live. Traditionally, all people have been free to use the atmosphere as a convenient medium for disposing of many of their waste substances. Thus, in these senses, the atmosphere is a common pool resource. In recent decades, however, the right to pollute has been significantly circumscribed by domestic and international laws and policies that restrict emissions of certain pollutants to enhance air quality in the common interest.

Air Space and Its Legal Status

Before proceeding with a discussion of the legal status of the atmosphere, it is important to distinguish the atmosphere, and the air that comprises it, from air space. Air space is the three-dimensional region located above a geographical territory on the surface of the earth. The air space located above a sovereign state and its territorial waters falls under the exclusive jurisdiction of that state, and is thus not a commons. Air spaces over other areas, such as the high seas and Antarctica, are beyond national jurisdictions and thus commons.

The legal status of air space above states was not an international issue until the invention of aircraft early in the 20th century. At first, two sharply divergent positions were espoused on the rights to use air space. The "open skies" doctrine would permit planes to fly freely above any state, which would parallel the principle of the "freedom of the seas" that has been applied to shipping. The doctrine is also applicable to satellites orbiting the Earth at much higher altitudes, or what is known as outer space. The opposing doctrine, or "closed skies," recognizes the right of states to exercise sovereignty over the air space above them, including the prerogative of regulating the movement of aircraft (Nayar, 1995, pp. 146-47). The latter doctrine soon won out, as states declared control over their air spaces, first to exclude hostile military aircraft during the First World War and later to preserve national monopolies over commercial air services to their cities. Before long national control of air space had become a widely recognized principle of international customary law (von Glahn, 1986, pp. 420-1). The principle was further defined and reinforced in a series of international agreements, most notably the 1944 Chicago Convention on International Civil Aviation, the first article of which provides "that every state has complete and exclusive sovereignty over the airspace above its territory," which includes land area and adjacent territorial waters.

Although the subject has been discussed extensively, no agreement has been reached on a specific upper boundary of air space (Akehurst, 1982, p. 287). It is generally assumed, however, that air space extends to the highest altitudes at which aircraft fly, or approximately 30 kilometers, while outer space, which is subject to a different body of international law, begins at the lowest levels that satellites orbit the earth; i.e., approximately 160 kilometers. Thus, the vertical dimension of air space encompasses all of the troposphere, the lowest layer of the atmosphere that includes 85 percent of its gases, as well as much of the stratosphere, in which the ozone layer is located. Having legal jurisdiction over air space, however, does not confer upon states absolute sovereignty regarding its use. The international customary law of state responsibility, which is increasingly being applied to environmental matters, obliges nations to ensure that activities taking place in areas over which they have jurisdiction do not cause damage to other states (see Vicuña, 1992). This doctrine is the corollary of the basic principle of state sovereignty, which recognizes the right of each state to maintain its territory free of outside interference and to protect the lives, property, and interests of its people. Pollution that a state permits to be emitted into its air space, which subsequently drifts into the air space of another state where it causes significant damage, is generally considered an infringement on the latter's sovereignty. Attempts to manipulate weather that have undesirable consequences in other states would also appear to violate the doctrine of state responsibility (Samuels, 1974). The 1963 ban on atmospheric testing of nuclear weapons is also a constraint on the way nations can use their air spaces (Taubenfeld, 1974).

The Legal Status of the Atmosphere

The atmosphere does not have a very well defined legal status (Birnie and Boyle, 1992, p. 390). States presumably have jurisdiction over the air that resides in their air spaces at any given time, just as they could lay claim to fish swimming through the 200-mile exclusive economic zone off their coasts or the water of rivers flowing through their territories. The atmosphere differs from these other moving resources in that it is impossible to impound and take control of substantial units of air in the way that fish can be caught and consumed, or river water can be dammed up and used for irrigation.

Rivers systems are shared resources, a legal designation which also can be applied to fish stocks and aquifers that migrate between or straddle national jurisdictions. An extensive body of international customary law and treaty law has been applied to the use of some of these shared resources based on the principles of limited sovereignty and equitable use. The widely acknowledged Helsinki Rules, which were drawn up by the nongovernmental International Law Association in 1966, suggests that "Each basin State is entitled, within its territory, to a reasonable and equitable share in the beneficial uses of the waters of an international drainage system" (Utton, 1974). The atmosphere as a whole is not properly categorized as a shared resource because at any given time more than half of it resides in air space above the oceans and Antarctica, and thus is outside the jurisdiction of any state (Boyle, 1991, pp. 8-9). The doctrine of equitable use may, nevertheless, have potential as a basis for an international law of the atmosphere.

Nor is the atmosphere appropriately categorized as either common property or the common heritage of mankind. Ever shifting parts of the atmosphere dwell temporarily within national air spaces and thus, at least in theory, are subject to the exclusive claims of the states located beneath them. This fact distinguishes the atmosphere from common property, such high seas, which refers to spatial areas that are always beyond the jurisdiction of any state. For the same reason, the atmosphere cannot properly be considered the common heritage of mankind, which implies that a domain is owned by all states (Birnie and Boyle, 1992, p. 391).

None of the treaties that address atmospheric problems takes up the question of the legal status of the atmosphere. The Vienna Convention and Montreal Protocol simply refer to the ozone layer as being "above the planetary boundary layer." The issue has also been sidestepped in talks on climate change. When Malta proposed to the General Assembly in 1988 that the global climate be designated the "common heritage of mankind"---as it had successfully done for the seabed two decades earlier---a compromise was reached on referring to the atmosphere by the vague phrase the "common concern of mankind" (Birnie and Boyle, 1992, p. 391). This language has been incorporated into several international documents, including the 1989 Noordwijk Declaration and the 1992 Framework Convention on Climate Change.

The Limits of the Atmosphere

For certain uses the atmosphere has the quality of jointness and has no limits, but for others it is subtractive and finite. All human beings can take advantage of the UV-B shielding qualities of the stratospheric ozone layer without diminishing its value to others or reducing its future usefulness. Likewise, there is no limit to the number of people who can take advantage of the climatic conditions maintained by the atmosphere, without interfering with one another. In these respects, the atmosphere provides what are called "pure" public goods.

Subtractivity comes into play for other uses of the atmosphere, although not in as apparent a way as with Hardin's pasture or an ocean fishery. Units of atmospheric gases consumed in the processes of respiration or combustion are not available to other users, and thus are subtracted from the totality of the resource. However, even with billions of people, the proportion of the available gases, such as oxygen, that are extracted in these ways is so infinitesimal that the atmosphere resembles a public good which is infinite in its supply of life-sustaining gases. Looking into the distant future, there is no reason for concern that human consumptive uses of atmospheric gases would deplete them in any meaningful way, because other environmental constraints would limit population growth well before this point would be reached.

Is the atmosphere a subtractive resource as a sink for pollutants? In one sense, there appears to be no physical limit to the amount of pollutants such as SO_2 and CFCs that can be suspended in the atmosphere, which would suggest that it can be subjected to unlimited joint use, and thus be considered a public good. The emissions of one actor do not prevent others from adding their wastes to the same volume of air, although the mix of pollutants will become increasingly noxious. In this sense, the atmosphere would be similar to rivers or large bodies of water for absorbing pollutants, but differs from a land fill that has a finite amount of space that once it is filled can accommodate no more garbage.

The picture changes, however, when it is recognized that there are limits to the capacity of the atmosphere to absorb certain pollutants without serious consequences for human health or the environment, such as respiratory diseases, acidification. or depletion of the ozone layer. Thus, the pollutants emitted into the atmosphere by one actor have the effect of subtracting from the amount that others can emit without bringing the total burden of pollutants to levels that have adverse impacts. The subtractivity of the atmosphere as a sink for pollutants is not very apparent from the perspective of individual sources, such as operators of motorized vehicles, because each one's discharges of pollutants are inconsequential compared to total human emissions as well as to the vast capacity of the atmosphere to disperse pollutants. The subtractive characteristic becomes more apparent when emissions are aggregated at the national or global levels. For example, a relatively small number of highly developed countries have already preempted a large part of the capacity of the atmosphere to absorb CO_2 without triggering significant global climate change.

The limits of the atmosphere as a sink for pollutants without serious consequences are not as easy to determine as the number of cattle that can be nourished by a village pasture. Many types of pollutants are released into the atmosphere, where they mingle and undergo complex chemical changes. Furthermore, each type of pollutant is but one of many factors that contribute to a myriad of consequences for human health and the environment, such as human cancers, disappearances of aquatic life, and waldsterben, making it difficult to establish cause and effect relationships. Causal links are further blurred by the lengthy time lags between when a pollutant enters the atmosphere and when it has an observable impact, which in the cases of radioactive fallout and ozone-depleting chemicals may be decades. Finally, the contributions that pollutants are making to environmental problems are more difficult to anticipate when there are few if any observable impacts until a critical threshold is exceeded, after which the damaging consequences mount quickly

TYPES OF TRAGEDIES

In the case of the pasture of the English village, the tragedy occurs when the grass of the pasture is consumed more rapidly than it is being replenished, with the result that not enough grass is available to nourish all the cattle being grazed on the pasture. Since grass is a renewable resource, the "tragedy" of the pasture could be a temporary problem, which may be remedied by keeping the cattle off the pasture until the grass grows back. The pasture may become permanently degraded, however, if the roots of the grass are disturbed by the hoofs of the cattle and the area becomes overgrown with weeds or the soil is exposed and erodes away. In the latter case, only an expensive reclamation will return the pasture to its previous productivity. Similarly, fisheries may be only temporarily depleted, in which case the stocks will regenerate themselves with time if fishing is temporarily suspended, or permanently degraded if they are severely overharvested and the prime species lose their niches in the food chain to other species.

The atmospheric "tragedies" resulting from pollution are of two basic types. The first results from the transport and deposition of pollutants by the atmosphere, as is the case with fallout from nuclear tests and acid rain. The atmosphere picks up pollutants emitted in one place and carries them laterally over the surface of the earth until they gravitate or are washed by rain back to the earth. For the most part, these pollutants remain in the atmosphere for a relatively short period--normally a few hours, days, or weeks, during which they may be transported several thousand kilometers and in the process cross one or more national boundaries. While suspended in the atmosphere, some of the pollutants, such as the precursors of acid deposition, undergo chemical changes as they are exposed to solar energy and react with moisture and other chemicals.

Transport-and-deposit types of pollution are generally not very troublesome while suspended in the atmosphere, although they may reduce visibility and be aesthetically displeasing. They may also block solar radiation, and thus have a slight cooling effect on the lower atmosphere, which to some extent may counter tendencies toward greenhouse warming caused by other pollutants. These types of pollutants do their damage when they leave the atmosphere by being inhaled or ingested by human beings or other species or are deposited on soil, vegetation, bodies of water, or building surfaces. The atmosphere returns to its original composition once it is rid of the pollutants. However, the human and environmental toll from the deposited pollutants may be long-term, if not irreversible, as in the case with genetic mutations caused by radioactive fallout or a freshwater ecosystem that is severely disrupted by acidic precipitation.

The second group of air pollutants are problematic because they trigger long-term atmospheric changes, in particular ones that alter the extent to which the atmosphere moderates the flow of energy moving to and from the earth. These pollutants generally reside in the atmosphere for much longer periods, some as long as decades or even centuries. CFCs and other substances that deplete the ozone layer never do gravitate out the atmosphere, but continue to rise until they are broken apart by intense solar radiation in the stratosphere. The principal greenhouse gases may eventually be absorbed by terrestrial or aquatic systems, but without causing significant environmental damage. In fact, CO_2 is an essential raw material for the growth of plants.

Because of the lengthy time this second group of pollutants resides in the atmosphere, curbs on emissions will take decades to have a significant effect on the problems they address. Eventually, natural processes may begin to restore the chemical composition of the atmosphere to its previous balance. Once the stream of new CFCs is interrupted, CFC molecules will gradually disappear from the atmosphere allowing the ozone layer to return gradually to pre-industrial concentrations. The oceans and green vegetation may gradually absorb some of the surplus CO_2, causing global temperatures to stabilize and eventually decline. However, some of the effects of greater doses of UV-B radiation and a warmer global climate might have on the biosphere and the earth system probably will be irreversible. Marine food chains may be altered permanently by the destruction of microscopic phytoplankton. Significantly modified patterns of vegetation and ocean circulation patterns caused by global warming could drive long-term or permanent changes in the earth system, including the composition of the atmosphere and climatic patterns.

TRAGEDY INDUCING BEHAVIORS

William Forster Lloyd and Garrett Hardin are but two of many writers who has warned of the tendency of users of commons to overexploit the resource domain to the point of its overcrowding, depletion, or destruction. Some commons are so vast that they can sustain unlimited human use for very long periods of time. The situation may change, however, if the number of users increases and they apply new technologies which magnify their impact. The carrying capacity of what once seemed like a boundless resource domain may be approached and overshot, sometimes much more rapidly than might ever have been anticipated. In recent decades, humanity has quite rapidly exceeded the capacity of the global atmosphere to absorb and disperse pollutants without serious environmental effects.

Ironically, the users of a commons may overexploit its resources even when they are fully aware of the highly undesirable consequences of their actions. Such behavior is the outgrowth of a rational assessment of self-interested actors who calculate that all the proceeds from using the commons will go exclusively to themselves as individual actors, while the environmental costs associated with overgrazing are shared with the entire community. Thus, a herder in the English village may decide to add more cattle to the common pasture believing that the profits from his cattle will be substantially greater than his share of the additional costs of overgrazing which are shared by all the villagers.

The behavior patterns that have contaminated and altered the atmosphere parallel those of Hardin's villagers, but the calculations of the polluters are more varied and complex. Those who pollute the air derive two types of private benefits: the proceeds from the activity that generates the pollutants and the savings from venting gaseous and particulate wastes into the atmosphere, which would be more costly to dispose of in other ways. As wind currents disperse the pollutants, the resulting environmental damages are spread over a larger area. Thus, from the polluter's perspective, his share of the costs resulting from his emissions may pale in significance in comparison with the benefits he derives from the polluting activity.

The incentive for using the atmosphere to dispose of pollutants is all the more compelling in the case of the transport-and-deposition type pollution, such as those that cause acid rain, especially when tall smokestacks significantly reduce the amount of pollution that is deposited near the emission source. In effect, the generator of the waste substances transfers, or externalizes, virtually all of the costs associated with disposing of waste substances to downwind areas, whose residents typically receive none of the benefits from the polluting activities. The down-wind victims often protest the injustice of this situation, as the Scandinavian countries and Canada have done in complaining about the large quantities of acid-forming pollutants they receive from the United Kingdom and United States. Similarly, numerous Pacific countries denounced the nuclear testing programs of the United States, Britain, and France in their region for exposing their populations to potentially dangerous levels of radioactive fallout. Meanwhile, the people of the distant states conducting the tests, who are the beneficiaries of the knowledge gleaned from the testing programs, received much smaller doses of "global radiation," which posed only a minor threat to their health.

The situation is somewhat different with pollutants such CFCs and CO_2 that trigger basic atmospheric changes on a global scale. The polluter again enjoys the benefits of the polluting activity, but is less able to avoid sharing the environmental costs, which are dispersed globally rather than primarily in downwind areas. No country can escape increased exposure to UV-B radiation due to a thinning of the ozone layer, although the effects will vary across geographical region. Similarly, all countries can expect to experience climate changes, but here again the types of changes and their severity can be expected to vary considerably from region to another. Nevertheless, the polluters may conclude that the benefits they derive from their polluting activities significantly outweigh their share of the costs of atmospheric change caused by their emissions. The consequences of atmospheric change will become much more troublesome, however, if other countries are guided by the same logic and add significantly to the global burden of pollutants, thereby accelerating the change process.

STRATEGIES FOR AVERTING ATMOSPHERIC TRAGEDIES

Human communities can adopt a variety of strategies to avoid overexploitation and degradation of a commonly used resource. None of them, however, is a sure bet for averting an environmental tragedy. How successful they are depends upon the circumstances in which they are applied, as well as on how they are implemented. One potential solution to the tragedy is to try to persuade the users to act responsibly by exercising voluntary restraint in exploiting their common resource domain, so that their combined use will remain within its carrying capacity. As part of the strategy, information may be provided to the users to impress upon them the undesirable consequences of continuing to exploit the common resource in an unrestrained fashion. A second strategy would establish regulations that limit the amount or type of use that is made of the resource domain. Such regulations may take various forms, such as bans, quotas, required equipment, or user fees.

Two other solutions to the tragedy would discontinue the commons system for utilizing a resource and replace it with alternative arrangements. Thus, a third course of action would be to partition the resource domain into sections, which are assigned or transferred to individual members of the community for their exclusive use. Under this so-called "privatization" solution, a user will presumably have a greater stake in conserving the resources of his section because he will absorb all of the costs from its overuse. The last option, known as the "socialist" approach, would have the resource domain utilized exclusively by a public enterprise, which would distribute what it produced or earned among the members of the community. Not being driven to maximize personal profit, the public managers of such an enterprise could, at least in theory, balance the goals of production and conservation of the resource (Soroos, 1992; see also Mirovitskaya and Soroos, 1995).

Each of these approaches can be readily envisioned in the case of the mythical English village. The residents could exhort each other to act responsibly by not adding more cattle to an already heavily grazed common pasture in the interests of preserving it. If voluntary measures failed, the village government could impose a limit on the number of cattle each household would be allowed to graze, with any surplus cattle being confiscated. Alternatively, the herders may be assessed grazing fees on each head of their cattle, which if set high enough would discourage excessive use of the pasture. Alternatively, the pasture could be divided into fenced sections assigned to individual villagers for exclusive grazing by each one's cattle. Finally, grazing could be limited to animals belonging to the community as whole, with the products and profits being distributed among all of the villagers.

A more limited range of approaches can be used to limit pollution of the atmosphere. Given the dynamic movement of air, it would be physically impossible to divide up the atmosphere into enclosed sections for exclusive use by individual actors. It is also inconceivable that an international public enterprise could be created which would have exclusive rights to pollute the atmosphere. Thus, the remaining possibilities for averting "tragedies of the atmosphere" are voluntary restraint and various regulatory mechanisms.

Voluntary Restraint

Hardin places little stock in voluntary restraint as an approach for averting a tragedy of the commons. Those who contemplate acting in an ecologically responsible manner may calculate that they will absorb all the opportunity costs of curbing their use of a commons, while the benefits of their restraint will be shared with the community as a whole. Those who exercise voluntary restraint in emitting air pollutants are in effect creating a public good in the form of less polluted air that will be shared by all. Few actors can be expected to be so altruistic on a continuing basis.

The incentive for individuals to act in an ecologically responsible way is likely to be undermined further by the prospect that others will not exercise similar restraint, but will maintain or even increase the rate at which they exploit the resources of the commons. The resource units one actor passes up for the good of the environment may be taken by a less scrupulous actor, known as a "free rider," who persists in trying to maximize what he derive from the commons. The more responsible members of a community may discover that are not only receiving a smaller share of the resource units, but are also being disadvantaged in their dealings with the free riders. For example, the industries of countries that have strict rules on air pollution will tend to have higher costs of production than do competitors in countries with laxer standards.

Frustrated that their self-restraint will have little effect on conserving the common resource due to the self-serving behavior of free riders, even the environmentally concerned actors may yield to the temptation to exploit the resource as rapidly as possible to secure a fair share of what it has to offer. Thus, the herders in Hardin's mythical English village continue adding cattle to an over-burdened pasture and fishing operatives invest in more and more boats despite signs that the fisheries they are planning to harvest are already declining.

Thus, it is paradoxical that a number of states have taken unilateral steps to reduce emissions of air pollutants that have either transboundary or global effects. In the late 1970s the United States, Norway, Sweden, and Canada enacted bans on nonessential uses of CFCs, including aerosol sprays, long before the establishment of international rules on the manufacture and consumption of ozone depleting substances. During the 1980s, twelve European countries committed themselves to reducing sulphur dioxide emissions that went well beyond the 30 percent cutbacks mandated by the 1985 Sulphur Protocol. Similarly, most industrialized countries unilaterally declared their intentions to freeze or reduce their emissions of CO_2 by the turn of the century, well in advance of the negotiations on the Framework Convention on Climate Change that began in 1991.

These unilateral actions appear to defy Hardin's logic in that the countries taking them will endure all of the costs entailed in reducing air pollutants to create a benefit that will be shared by the larger community of states, including the free riders that are doing nothing to curb their emissions. Unilateral reductions by large states that are responsible for a sizeable proportion of global emissions, such as the United States in the case of CFCs, are more understandable, because their restraint can make a significant contribution toward addressing an environmental problem. What may be very costly steps by smaller states, such as the Nordic countries, Denmark, Austria, and Switzerland, to reduce their much lower volumes of emissions will have little effect on the overall problem. Yet in the case of the pollutants that are the precursors of acid rain, it was the smaller states such as the Nordic countries that were in the forefront in making unilateral commitments to reduce emissions of SO_2 and NO_x.

How can these unilateral commitments of states to reduce pollutants can be explained? They may simply be a response to domestic political pressures from an aroused citizenry, and nongovernmental organizations as well, for their governments to do whatever can be done within their jurisdictions to address environmental problems of growing concern. Such was the case with the American ban on nonessential uses of CFCs that was adopted in 1978. In such cases, domestic publics may not even seem not to be concerned about whether other countries are taking reciprocal steps, nor dwell on the small extent to which their sacrifices will mitigate the larger problem.

Alternatively, unilateral pronouncements may be part of a strategy for influencing other states to make similar commitments to reduce pollutants, which seems to have been a major factor in the decision of the Nordic countries to get far ahead of other European countries in reducing emissions of SO_2. As countries whose acidification problems were caused largely by air pollution originating beyond their borders, their task was to persuade the up-wind states to take corrective action. By unilaterally setting ambitious goals for reducing air pollution and then achieving them, the victimized states could undermine the rationales that offending states frequently cite for their failure to curb their emissions: first, that the complaining state was not concerned enough about the pollution problem to do what it could on its own to mitigate it, and second that substantial reductions are technically impossible or too costly. Thus, the declarations may be part of a strategy by concerned "pusher" states to lend momentum to the process of negotiations on international conventions and protocols that would commit all parties to reduce emissions of pollutants. This appears to have been the primary motivation behind the unilateral goals set by of numerous developed countries in the late 1980s on stabilizing or reducing CO_2 emissions. Without the prospect of negotiating such an agreement, substantially fewer states may have been inclined to set these goals.

These unilateral cutbacks have been only a very small part of what is needed to address the problems of acid rain, ozone depletion, and climate change. It will be necessary for many more countries to make similar, if not more ambitious commitments, if these problems are to be kept from intensifying. Nor can it be assumed that the countries making unilateral reductions will continue to sacrifice for the welfare of larger community unless other key states reciprocate. In 1980 the United States backed away from taking further steps to reduce its production and consumption of CFCs, as long as other major countries were profiting from playing the role of free rider by failing to phase out their nonessential uses of CFCs. Likewise, some countries have warned that their announced goals of reducing or stabilizing CO_2 emissions were contingent on other states making similar commitments.

Regulations on Air Pollution

Since states are unlikely to take strong enough action on their own to avert major global problems such as acidification, ozone depletion, and climate change, international regulations appear to offer the only hope for preserving the critical qualities of the atmosphere. Applicable rules may be found in international customary law, such as the responsibility of states to prevent damage to other states or to areas outside any jurisdiction. These principles of customary law have proven to be too vague, however, to define limits on polluting activities, especially where specific sources of pollution cannot be definitively linked to specific damages. Thus, it has been necessary to draw up more specific mandates for states in the form of negotiated treaties that are binding on ratifying states.

The simplest and most decisive form of regulation is a <u>prohibition</u> on activities that cause environmental damage. A temporary ban may be enacted to allow a resource to recover from overuse, an example being moratorium on commercial harvesting of whales that was put in place by the International Whaling Commission in 1986. Permanent bans may be imposed on uses that are considered to be intrinsically harmful to the environment, such as the testing nuclear weapons in the atmosphere. Similarly, the 1992 Copenhagen amendments to the Montreal Protocol provide for a permanent end to the production and use of CFCs and certain other chemicals that pose a threat to the ozone layer. Bans are practical when the activity generating the pollution can be discontinued without prohibitive costs or serious disruptions. The superpowers agreed to stop nuclear tests in atmosphere after underground testing became a viable option. Ozone depleting substances were phased out only after the leading chemical companies expressed confidence that affordable chemical substitutes could be produced in a timely way.

A second type of regulation merely sets a <u>limit</u> on the use of a commons at a level that can be sustained without serious damage to the resource. The limit may be on the aggregate use of the commons by all parties, with users helping themselves to its resources on a first-come, first-served basis until the limit is reached. Alternatively, each of the individual users could be allocated a share of the total allowable use, or what is known as a quota. The quotas may be the same for all members of the community, or they may vary considerable, based on criteria such as the size of the parties, proximity to the resource, previous level of use, or special needs for the resource. The limits written into the early international agreements on atmospheric pollutants have in most cases been freezes or percentage reductions in emissions that apply uniformly to all parties, such as the 30 percent reduction in SO_2 emissions mandated by the 1985 Sulphur Protocol and the 50 percent reduction in CFC production and consumption specified for the parties to the 1987 Montreal Protocol. By specifying uniform percentage changes for all parties, these regulations have the effect of setting national quotas based on previous use of the atmosphere as a sink for the pollutants in question.

A third type of regulation specifies <u>operational rules</u>, such the type of equipment, that can be used in exploiting the resources of a commons. For example, rules on the minimum size of mesh in fishing nets have been adopted to allow younger specimens to grow to maturity and reproduce. Air pollution can be reduced significantly by requiring use of certain technologies, such as catalytic converters in the exhaust systems of automobiles or flue gas desulphurization equipment in the smokestacks of power plants. Reductions in air pollution may also be achieved by imposing rules on the sulphur content of fuels that are burned in power plants. While such operational rules are frequently key provisions of national environmental laws, there has been considerable resistance to including them in international agreements on air pollution, except in a vague way such as "the best available technology that is economically feasible" clause that appears in the 1979 LRTAP convention.

Economic disincentives based on the "polluter pays" principle are a fourth way of regulating use of a commons. The residents of the English village might be required to pay a tax on the cattle they own above a certain number, which would deter further additions of cattle to the pasture. National governments use taxes to discourage certain types of air pollution, such as fees on the sulphur or carbon content of fuels or on the volume of smokestack emissions. States have not been willing, however, to conclude agreements that would impose international taxes on their pollutants, or require all of them to adopt national sulphur or carbon taxes.

Rules of liability can also be a form of economic disincentive if polluters anticipate they will be compelled to compensate the victims of their emissions for the damages they suffer. In international customary law, a state may demand compensation for harms to its people or environment caused by pollutants originating in other states, but the accused state has the legal prerogative of refusing to be sued. The Trail Smelter Case between the United States and Canada is one of very few instances of a state, namely Canada, conceding that it should pay compensation to foreign victims of pollution originating within its borders, but the amount was only $78,000. The concept of liability offers little recourse for those harmed by pollution that cannot be linked exclusively to a specific source, as has been the case with acid deposition, ozone depletion, and greenhouse warming.

Thus, to this point most international efforts to regulate air pollution have simply dealt with deciding how much states should be allowed to pollute. These amounts, as contained in international agreements, have been expressed not in absolute amounts of pollution, but either as a freeze at existing levels or a certain percentage reduction that is to be achieved by a specified date by ratifying states. In negotiations on atmospheric treaties, most states have insisted on retaining the right to choose the strategies they would use to comply with the prescribed limits on their emissions, taking into account their unique circumstances. In doing so, states have experimented with a wide variety of national regulatory instruments, such as equipment requirements, rules on the sulphur content of fuels, carbon taxes, and tradeable emission permits.

GOALS OF COMMONS MANAGEMENT

The potential of a regime for effectively managing a common resource can be evaluated using several criteria. From an environmental standpoint, the most critical question is whether the regime will be successful in conserving the resource domain. In other words, will it prevent a "tragedy of the commons"? Two economic questions may also be important considerations. Will the regime allow for the greatest possible sustainable use of the resource domain? And, will the regime encourage the most efficient use of economic resources in the exploitation and conservation of the commons? Then there is the issue of equity. Will the rules for exploiting the common resource be fair to previous and potential future users? Finally, there is the critical matter of feasibility. How likely is it that management scheme could be put in place and effectively implemented?

Conservation of the Resource Domain

The most certain way to conserve a resource domain would be to prohibit completely the types of uses that are becoming excessive. The ban on testing nuclear weapons in the atmosphere promptly and decisively reversed trends toward increased deposition of radioactive fallout, especially in the regions were the testing was taking place, but globally as well. Further damage to the ozone layer will be minimized with the worldwide rules phasing out the production and consumption of most of the chemicals that have been linked to its depletion.

The extent to which other types of regulation achieve environmental objectives hinges on how restrictive they are. Limits and quotas can be set low enough, operational rules stringent enough, or economic disincentives high enough to keep use of a commons from exceeding the level that can be sustained indefinitely. Unfortunately, political and economic considerations often lead to the adoption of measures that fall short of what is needed to achieve environmental goals. Thus, acidification continues to become more severe in Europe despite the limited cutbacks in emissions of SO_2, NO_x, and VOCs that were mandated by the protocols added to the 1979 LRTAP convention.

Maximum Sustainable Use

Commons are susceptible to environmental tragedies because of the economic value of the resource units they contain. While a total ban on certain uses of a resource may be the simplest way of preventing its overuse, such a policy may arbitrarily deny potential users the possibility of enjoying what the resource can provide them on a sustainable basis. The English villagers would hardly be acting rationally if they were to remove all their cattle from their common pasture, thus losing the income that could be generated from a sustainable level of use of the resource. Likewise, it is not necessary to completely ban emissions of many air pollutants, such as SO_2 and CO_2, to avoid significant threats to human health and the environment.

Limits and disincentives are more flexible types of regulatory instruments which, if properly calibrated, can permit maximum sustainable use of a common resource. International fishery commissions have sought to limit the annual catch to a scientifically determined "maximum sustainable yield." The LRTAP regime has adopted the concept "critical load" to designate the amount of deposition of air pollutants that can be permitted without serious environmental consequences. Assigning each actor a limit, or quota, on its use of a resource may result in less than the maximum sustainable use if some actors do not take full advantage of their allocation, either because they lack the means or the incentive to do so. The resource domain might be used more fully if quotas are distributed in the form of tradable permits that can be bought and sold in special markets. Such an arrangement was introduced for sulphur pollution in the 1990 amendments to the Clean Air Act of the United States, but has yet to be tried internationally, although it is being considered but not adopted by in the European Union.

Economic Efficiency

Increasingly, environmental policies and regulations are being evaluated on the criterion of whether conservation of the resource will be accomplished in the most cost-effective way. Rules that mandate how emission reductions are to be achieved have been widely criticized for not allowing polluters to opt for the least expensive ways of achieving specific environmental objectives. For example, installing costly pollution abatement technologies mandated by law, such as flue-gas desulphurization equipment, may be a much more costly way for power plants to achieve a specified reductions in SO_2 emissions than other alternatives, such as shifting to fuels with a lower sulphur content. Limits or taxes are generally preferred on economic grounds because they allow polluters to opt for the least expensive way of reducing pollutants, taking into account their own circumstances. The target dates for percentage reductions of pollutants that have been written into several international agreements, such as the protocols of the LRTAP and ozone regimes, permit states to devise national strategies that minimize costs and economic dislocations.

Requiring the same percentage reduction of pollutants by all countries may not, however, be the most cost-effective way of reducing environmental impacts on a regional or global scale. Thus, the plan for the Revised Sulphur Protocol of the LRTAP regime proposed different percentage SO_2 reductions for each country. The objective was to tailor country-specific targets to concentrate the cutbacks where they would not only do the most to close gaps between actual deposition and critical loads, but could also be implemented at a relatively low cost. Another cost-efficient strategy is known as "joint implementation," which is being experimented with in the climate change regime. Under its terms, technologically advanced countries, which have previously invested heavily in controlling emissions to the point of rapidly diminishing returns, would be given the much less costly option of assisting other countries take their first, and much less costly, steps toward limiting pollution.

Equity

Equity is an especially important consideration issue in the negotiation of international agreements. States that are not satisfied that a proposed treaty is fair to them will be reluctant to become signatories and ratifiers, and thus become bound to its provisions. Equity does not necessarily imply equality, nor is equality always interpreted as being equitable. Thus, bans may be considered unfair even though they may apply equally to all states. When adopted in 1963, the Limited Test Ban Treaty was not considered fair by China and France because it would deny them the same opportunity that the United States, the Soviet Union, and the United Kingdom had prior to the agreement to use atmospheric testing to develop their nuclear arsenals. Alternatively, carbon taxes are widely looked upon as being equitable because they are based on the "polluter pays" principle, even though some polluters may pay much more than others.

Issues of equity have frequently arisen in negotiations on international agreements that would freeze or reduce emissions of air pollution. States that have unilaterally enacted measures that have already substantially reduced or limited certain air pollutants may question whether they should be expected to achieve the same future percentage reductions as states that have done much less, if anything, to reduce their emissions. One way to acknowledge previous reductions is to push back the base year against which the percentages will be calculated, as was done in the case of the 1985 Sulphur Protocol, which designated 1980 as the base year in calculating pollution emissions.

States that historically have had disproportionately low emissions of air pollutants may also challenge the fairness of treaties mandating uniform percentage reductions for all countries. Should Japan, for example, which has always been much more frugal in its use of fossil fuels, be expected to reduce its CO_2 by the same percentage as the United States, even though in 1990 the average Japanese was responsible for less than half as much CO_2 emissions as the average American? Developing countries sometimes take the argument one step further by arguing that fairness dictates that they should be entitled to increase their release of air pollutants if necessary to implement their development plans, even while the industrialized counties are expected to achieve reductions in their much higher levels of pollution. This principle is acknowledged in the Framework Convention on Climate Change of 1992 in which there is no expectation that developing countries will limit their emissions of CO_2

These issues of equity might be rephrased in terms of how a finite quantity of permissible pollution should be divided among the peoples of the world. Do all people have an equal right to pollute the atmosphere? If not, on what grounds should some people be permitted to pollute more than other? If it is accepted that all people have an equal right to pollute, then states might be allocated pollution permits based on their population at a certain date. Making the permits tradeable would not only encourage an efficient use of resources, but also trigger a financial flow from high to low polluting states, or in effect from the developed to developing countries.

Feasibility

Regardless of whatever desirable qualities a prospective scheme may have for managing a commons, it is hardly worth consideration unless it is feasible, meaning that it has a chance of being successfully instituted. The fluid physical quality of the atmosphere rules out the option of dividing it into sections assigned to states for their exclusive use. The range of possibilities is also constrained by what is politically possible, given that international regulations are not legislatively imposed, but are the product of negotiations that are normally a slow and cumbersome process, especially when they involve large numbers of countries with divergent interests. Furthermore, the sovereign states participating in international negotiations have the prerogative of refusing to be bound by the rules agreed to by others. These realities of the negotiation process in part explain why the regulations of the atmospheric regimes have been largely limited to relatively simple types of rules, such as bans or reductions based on previous levels of air pollution.

Agreement on strong, effective rules is unlikely unless there are plausible ways of monitoring compliance. Efforts to reach agreement on a comprehensive nuclear test ban were repeatedly frustrated by uncertainties about whether test explosions could be detected, especially underground ones. The Partial Test Ban Treaty of 1963 could be concluded because nuclear tests in the atmosphere, outer space, or oceans would be difficult to conceal. Bans are generally less complicated to monitor than limits, because any instance of a prohibited activity can be assumed to be a violation. Assessing compliance with limits usually requires a more elaborate system of collecting information, either a self-reporting procedure that is sufficiently transparent to permit outside scrutiny or an international monitoring network, such as LRTAP's EMEP, which has provided figures on emissions of air pollutants that are generally accepted as being valid.

CONCLUSIONS

In certain respects, the atmosphere does not fit the classic mold of a commons as exemplified by the village pasture in Hardin's parable of the "tragedy of the commons." Rather than being a typical resource domain from which things are physically taken and consumed, such as fish in the oceans, the threat of overuse of the atmosphere comes from unregulated use of it as a medium for disposing of pollutants. Nevertheless, the atmosphere has the essential properties that distinguish commons. As a resource domain its resource units are used by multiple actors for their individual benefit. It is finite in its capacity to absorb pollutants, and the pollution that one country introduces into the atmosphere ultimately reduces the amount of pollution that others can discharge without triggering harmful environmental effects.

Some may question whether the atmosphere is appropriately classified as a commons, since at any given time, much of the air that comprises it resides within national air spaces. Thus, states would seem to have a legal claim to jurisdiction over the air currently in the air space above their territory. Because air masses are constantly moving and defy containment in large quantities, it would be impossible for states to exercise exclusive control over any significant part of the atmosphere. Therefore, for all practical purposes, the atmosphere is a single common resource and recent international agreements refer to it as the "common concern" of humanity.

International regulatory regimes offer the only realistic possibility for limiting the amount of air pollution of either the transport-and-deposit or atmospheric change types. that is dispersed across national boundaries before being deposited or alters the basic chemical composition of the atmosphere. But even under the best of circumstances, it is a very cumbersome process to get large numbers sovereign states with widely divergent interests to agree on any type of rules, including simply limits on air pollution. The task would be difficult enough if conservation of the common resource was the only objective, but other considerations need to be taken into account, including maximizing use of the resource, achieving economic efficiency, and satisfying issues of equity.

Thus far, the regulations contained in international agreements on air pollution have been largely limited to prohibitions, freezes, or percentage reductions, although in some agreements states have been expected to the adopt to best available technologies for abating pollution that are economically feasible. The ban on testing nuclear weapons in the atmosphere has largely eliminated the radiation problem it was designed to address. The Vienna Convention and the Montreal Protocol as revised should, if observed, eventually halt depletion of the ozone layer. Deeper reductions in emissions of pollutants are needed to reverse acidification due to transboundary pollution. Effective abatement of the acidification and climate change problems may require the adoption of a greater assortment of international regulatory mechanisms than has been used previously in managing use of the atmosphere. International efforts to address the problem of climate change are only in the early stages.

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