Environmental Health Perspectives
Vol. 10, pp. 215–222, 1975

Overview: Biological Consequences of Environmental Control

by Michael Treshow*

The atmosphere of the planet earth is not pure today and it was not pure millions of years ago when man struck his first fire. The air then, composed basically of nitrogen, oxygen, and carbon dioxide, contained also a myriad of abundant chemicals including sulfur, ozone, various oxides, hydrocarbons, and terpenes. The air was locally more pungent near volcanoes, or perhaps where man dwelled, or much later in the mines and near the furnaces of industry. Far larger areas were fouled during the age of industry and technology, but many decades passed before a few countries reached a plane of affluence that enabled them to recognize the hazards and nuisance of pollution and respond.

In the United States, major constraints on air pollution were imposed during the 1920's, and the smoke from industry was markedly reduced. But by the 1950's, control measures failed to keep pace with growing industrialization, rising needs for electric power generation, and most devastatingly, a tremendous increase in the numbers of automobiles. More significantly, the economy had reached a degree of affluence where we could afford to be concerned.

* Biology Department, University of Utah, Salt Lake City, Utah 84112.

The quality of the air sufficiently worsened, and public indignation became so great that by 1967 Congress passed a Clean Air Act designed to reduce the amount of air pollution. A much amended Act in 1970 established the framework for setting air quality standards sufficiently stringent to protect the health of man and the most sensitive kinds of plants and animals.

Four years later, these standards have been met around a few industries, and effective pollution control equipment installation will probably be completed at remaining industries within the next few years to achieve the primary goals.

The prospects for improving air quality of urban areas, where automobiles are the major pollution source, are less promising. However, emissions from the auto, despite their increasing numbers, are gradually coming under control as evidenced by the slightly diminishing amount of photochemical pollution in the Los Angeles area.

Ultimately, perhaps within the next decade or two, the quality of air over major cities will return to a pre-World War II degree of purity, and the air surrounding the industry and power plants of the U.S. will be cleaner than at any time since the birth of the industrial revolution.

Misinterpretation of Programs

Four years after passage of the 1970 Clean Air Act, we are inclined to view primarily, and perhaps myoptically, only the primary and beneficial effect of environmental controls, but we must also explore the unexpected, and perhaps undesirable secondary effects of succesfully implementing these controls. What unforeseen, untoward effects of controls might be anticipated? Only by recognizing and anticipating such events can they be averted, or their chances of happening be reduced. It is the purpose of this paper to explore the possible secondary biologic consequences of successful implementation of environmental control programs. To consider rationally the consequences of implementing environmental controls, we must first assume that there is an impact or biological effect in the absence of controls so that any changes from affecting controls could be measured; and secondly, we must assume that pollutants can be controlled. Then we must consider the natural sources of "pollution", and evaluate their significance.

There are several instances where a program that initially seemed only beneficial proved otherwise. Only much later were the unforeseen consequences revealed to have disarming effects. In other words, solving one problem only created more serious new problems. Such was the case, in one classic example, when DDT was used to control agricultural and horticultural insect pests over much of the world. During the years that DDT was so widely used, its persistent nature was not recognized, and once recognized was ignored. The tangible benefits were considered to outweigh the potential risks. Ultimately though, the perseverance of this chemical in nature, plus its capacity to accumulate in organisms, was considered sufficiently dangerous to warrant discontinuing its use. Now DDT and related chlorinated hydrocarbons are used only where no suitable substitutes exist. But meanwhile, DDT and its breakdown products persist in the environment throughout the world.

A second undesirable and unforeseen consequence of a short-sighted program was the mandatory conversion of many coal-fired power-generating facilities to natural gas or oil. Despite objections by some that these fossil fuels were in short supply and should be conserved, the urgency of pollution control dictated the switching to petroleum or gas. The more practical approach of controlling the pollution in the coal-fired plants was deemed too costly and ineffective. Now that a shortage of petroleum has been recognized, the power plants are converting back to coal and installing the necessary control equipment. Time, expense, and resources could have been conserved had adequate controls been used in the first place.

In another example, one of the world's greatest air pollution problems was the soot and sulfur dioxide of the London atmosphere. As this problem was brought under control in the 1960's, more and more light was able to penetrate the local atmosphere. This, coupled with the increasing numbers of automobiles, allowed photochemical pollution to develop to where this now, perhaps, presents a greater hazard than the original type of pollution.

Meanwhile, in the United States, photochemical pollution already presented a major problem. Initial control efforts were directed toward removing hydrocarbons and carbon monoxide from automobile exhausts. The early crankcase blowby devices and modified engine designs to create higher combustion temperatures partly served toward this end, and by the mid 1960's the amount of injury on vegetable crops from these pollutants seemed to diminish—at least the classic type of injury attributed to "smog." But another type of injury appeared to be more prevalent. This was due to NO_x, which had become more abundant in the Los Angeles atmosphere as a result of reducing the amount of hydrocarbons. Thus the nature of the injury changed but did not lessen. The same automobile emission control devices apparently

shifted the kind of pollution in the Los Angeles area. More seriously, perhaps, the catalytic devices may add platinum and palladium to the atmosphere causing a health hazard. The devices used to control evaporation collect the hydrocarbons but tend to cause an increase in the carbon monoxide released. The new controls also cause greater amounts of sulfuric acid mists to be released into the atmosphere. This, among other things, causes a decrease in visibility. Furthermore, the devices add to the operating costs of the car and to the number of things that can go wrong with it. Equally seriously, the devices also decrease the efficiency of the engines requiring them to burn approximately 20% more fuel to travel the same distance. This not only further strains the remaining petroleum supply but partially negates the benefits of the control program.

In another example of a misguided effort, it has also been noted that while converting SO_2 to sulfuric acid has been effective in controlling SO_2 emissions from smelters, the SO_3 concentrations have sometimes been observed to increase. Thus the hazard to plant life has been reduced but the hazard to man increased by the more toxic SO_3.

Another example of changing the form of the pollutant in attempting to achieve certain air quality goals occurred when a method was used to control sulfide emissions from paper pulp mills by oxidation. Sulfide levels were reduced, but the concentration of sulfur oxides increased, raising the threat to vegetation from SO_2. Now SO_2 injury is sometimes a problem around pulp mills where it rarely was before. Fortunately, most pulp mills have now gone to a newer process in which SO_2 is not evolved.

Tall Stacks in Pollution Control

In the early days of emission control, the major thrust was in attempting to reduce the ground level concentration of the pollutant. This was accomplished by releasing the waste gases through tall stacks. These stacks grew increasingly taller as emissions increased, until today many exceed a thousand feet in height and a few exceed 1200 ft. These stacks have accomplished the goal of reducing the ground level concentrations nearest the stack, particularly of sulfur, to levels nontoxic to plants. At the same time though, the tall stacks increased concentrations further out where the SO_2 had not reached with a short stack. This raised a further question: What are the less obvious effects of the lower SO_2 concentrations if plants are exposed for a much longer duration? The effects of high concentrations had been recognized for decades. Symptoms of injury were visible on plants surrounding certain industries, as were even the less obvious growth and production suppression. Compared to the obvious yellowing and browning of leaves, the insidious effects of pollution received little attention. Now that the visible symptoms are gone, more concern is being directed toward understanding and measuring the more subtle growth responses and the possible effect on the total ecosystem. If the ground level concentrations remain below even a sublethal level, however, there should be no problem.

Research to date indicates that little or no suppression of growth occurs from SO_2 in the absence of visible leaf injury. Therefore, it is unlikely that further improvement of the air quality will increase productivity around SO_2 sources. The only improvement would perhaps involve the rate of revegetation in the areas once made depauperate by emissions and the esthetic value in improved visibility if particulate wastes were also removed.

In areas where plant damage has been serious, controls will allow the sensitive species to return. Conceivably, but not likely, the plants might be undesirable types. In all cases observed, the natural species that are most tolerant have been the first to reinvade disturbed areas, and no negative biological consequences from further reducing emissions can be foreseen. The main impact would be social and economic, in that the added costs of control might not warrant the benefits of removing the last few tons of SO_2. The im-

pression is sometimes given that great economic losses are often sustained around industries even in the absence of visible leaf injury, but few or no data exist to support this contention. The field research needed to obtain scientific data has not been conducted.

The taller stacks still used to improve air quality have the particularly marked disadvantage that they enable the effluent to be dispersed further into the global as well as local atmosphere. Ultimately, somewhere, it returns to earth, and it may settle in normally pristine areas that once had truly clean air. These gases usually impact on larger particles of dust and settle out, thus increasing the sulfate level of the soil, or the SO_2 may settle out in the rain. In either case, sulfuric acid may be formed and the surrounding streams and lakes made more acid. This has always occurred around such natural sulfur sources as volcanoes, hot springs, or marshes, but in recent years considerable attention has been given to the formation of acid mist or rain from manmade sources. However, since the effect of such acidity has not been established, it is not likely that further reduction of sulfur will bring about any measurable change.

Ecosystem Effects

Recent biological research efforts have been directed toward studying the impact of pollutants on ecosystems, specifically plant communities including such natural flora as fungi and lichens. Disrupted systems and heavy plant mortality have been obvious for hundreds of years adjacent to areas where metal ores were smelted by open roasting. Sensitive plants were damaged or killed many miles away and thousands of acres of forests sometimes laid bare. Still more forests were cut to fuel the roasting heaps and furnaces in which the ores were refined. These forests have been returning as emissions have been controlled. Their rate of return is determined in part by the kinds of plants present, the current SO_2 concentrations, and very likely the residual toxic metals such as arsenic that remain in the soils surrounding the smelters.

Ecosystems are normally in a constant state of flux or change. The presence of one dominant species characteristically alters the environment so that growth of other species is favored until a relatively permanent climax plant community develops.

Air pollutants in a few instances have disrupted this vegetation so that a new succession was initiated. The time required for the climax community to return will depend on the degree of disruption of vegetation and soil and the extent to which the toxic pollutants persist. As the air is cleaned, however, the vegetation will return around the world's smelters and power plants.

The real question concerns areas where photochemical pollutants have been disruptive. Here, the likelihood of meeting air quality standards is more remote. But should they be met, what changes might be expected? The dominant Ponderosa and Jeffrey pines in the mountains north and east of the Los Angeles Basin have been dying out since the mid 1950"s, when concentrations of pollutants rose markedly. The impact to the rest of the plant community is not known, nor is the effect on the chaparral community surrounding the Los Angeles Basin at a lower elevation where oxidant concentrations are higher.

Apparently, the chaparral plants are remarkably tolerant, to judge from the lack of observations on their having been damaged. Consequently, it is not likely that improving the air quality will have much effect on this type of vegetation.

At the higher elevations, though, where more sensitive plants are native and the impact is pronounced, the changes should be more evident. One might, for instance, expect more tolerant plants such as Coulter pine to fill the voids left by the sensitive plants that have been killed or weakened. This may be happening to some extent, but many of the sites vacated by the Ponderosa and Jeffrey pine are too dry for the more moisture-requiring Coulter Pine. As the air becomes

cleaner though, more sensitive plants may return, including both understory and dominant species, if an adequate seed source is available. But since such a large part of the Ponderosa and Jeffrey populations have been killed, the seed source has been drastically reduced.

To further aggravate the situation, contiguous parts of the forests, barely out of the zone of pollution damage, are being logged off, further reducing the seed source.

Major losses might be averted by reforesting with trees that are resistant to the pollution. This has proven successful in some countries such as Czechoslovakia, where reforestation is a major mechanism of air pollution control, but in the U.S. the program has barely begun. If the forest is to be restored, replanting is the most likely way to achieve restoration, at least in our time.

Natural Ozone Tolerance

In any population of organisms, notably plants, there seems to be a few resistant individuals, and one can find a few unaffected pines even in the most polluted areas. The progeny of these trees might ultimately reforest the polluted areas.

It is worth noting that plants have always been subjected to ozone, the only question is how much. Even today we are not certain of the background concentrations. We know that a dense ozone layer exists at about 60,000 ft and suspect that some of this occasionally may reach the earth, or ozone may be generated in the biosphere. Some ozone is also produced by lightning and other local discharges and sources. Background concentrations in such remote areas as Bryce Canyon National Park have been measured to exceed 2 parts per hundred million (pphm), and a few reports from the east suggest still higher background levels where hourly averages may range from 15 to 20 pphm. The methodology of sampling and analysis still leaves much to be desired though. The average background values sometimes reported turn out to be higher than found in such large cities as Salt Lake City, Phoenix, or even San Francisco, where plant injury has been observed. The peak levels that are toxic apparently occur in urban areas while possibly not in the rural areas even though the averages may be higher. Also, the high concentrations in remote areas seem to occur just as much at night when the plant stoma are closed, in contrast to the urban peaks that occur during the day.

The main point is that plants have evolved in the presence of ozone and we shall always have to contend with this chemical. Perhaps plant breeders, working in slightly polluted areas, have even inadvertently selected for ozone tolerance and incorporated strains favored by ambient ozone levels. In fact, recent data indicate plants grow better in ambient than filtered air. Thus, cleaning the air might reduce production, although scarcely measurably.

Occasionally, hypersensitive individuals might appear, but these presumably would not be able to compete with less sensitive individuals. Perhaps such particularly sensitive plants were the first found to show symptoms of pine blight when the disease was first described in 1908. Only 60 years later was pine blight found to be caused by ozone.

Natural Pollution Sources

At this point it might be well to mention some of the other pollutants arising from natural sources. As we espouse the hazards of smoke and ban or limit open burning, we tend to ignore the occurrence of fire as a natural component of the ecological system. Fire, often started by lightning, has always been with us. There are species such as lodgepole pine that grow only following fire. The plants even remotely near large fires are subjected to carbon monoxide, hydrocarbons, and other by-products of combustion. This is not going to be changed when air quality standards are implemented, and we should not expect that it is.

Smoke from fire, whether from forest

fires, agricultural burning, or incineration, contributes to air pollution and cannot be controlled: a ton of plant material when burned releases 166 lb of organic gases and some 600 lb of carbon monoxide. Significant amounts of the more phytotoxic ethylene are also released.

Nor is the natural emission of terpenes, phenols, and other volatile chemicals released by all species of plants going to decrease with implementation of air quality controls. The terpenes and essential oils evaporate into the air to produce the pungent and characteristic odors of the seashore, chaparrals, desert, or pine forests. There is hardly any kind of plant that does not emit volatile organic compounds of some kind, including methane. When released, like the chemically similar hydrocarbons from gasoline, they probably easily form ozonides and peroxides in the air. Plants may release several hundred pounds of organics per acre. The blue haze often shrouding forested areas has long been recognized as a function of the chemicals released by plants, particularly in such areas as the Amazon Basin or even the Southeastern United States. The fate of these organic plant by-products is still unknown, but they undoubtedly contribute to the global "pollution" load. Even the plankton of the sea releases significant quantities of aromatic hydrocarbons. The organic vapors occur in the parts per billion range which can now be measured and is being considered in air quality standards.

Similarly, products of biological oxidation from oxidation ponds and from the sulfur bacteria of marshes contribute to the total pollution. Under anaerobic conditions, sulfur bacteria release hydrogen sulfide as a by-product of respiration. Usually, the numbers of bacteria remain nominal, but under periods of prolonged flooding, they multiply rapidly and exist in such large numbers as to produce significant amounts of sulfides.

Far more pollution in the form of sulfur is released from the volcanoes of the world. This is not going to stop and must be considered a natural component of the atmosphere.

Dust provides a major source of particulate pollution. In the southwest deserts that have been intensively grazed for over a hundred years, particulate matter contributes much more to air pollution than the smelters and coal-fired power plants located in the same areas. When all the wastes directly caused by man's activities in this area have been removed, the background concentrations will still exceed the secondary air quality standards in many areas because of man's earlier practices of grazing excessive numbers of livestock. This practice is still receiving scant attention, although the sheep and goats continue to decimate every palatable plant species. Land restoration might well be a consideration of air quality programs.

Trail bike riding also aggravates the pollution. In California, salt from the playas can be found throughout much of the state, and if the Bureau of Land Management allows off-trail vehicles on more of the land they administer, salts and dust may be transported over to the Rockies and possibly beyond.

Nor can pollen be ignored; it will always be with us, and as man-made pollutants are eliminated, pollen, along with other natural "pollutants", will comprise an increased proportion of the total atmospheric pollution load.

Implementation of Standards

One way of looking at the biological consequences of implementing air quality standards is to study areas where this has been successful. There are areas in this country where the air is still in a pristine state, and other areas where standards are exceeded by natural pollution sources more frequently than by those from man.

We can also go back in recent history to a time when the air was free from human wastes, at least as far as photochemical pollution was concerned. It is difficult to imagine

any adverse affects from clean air. One has only to go back 25 to 30 years in time to remember the days when oxidant air quality thresholds were not reached even in Los Angeles. In other cities, particulate levels were typically far in excess of what we measure today. From a pollution standpoint, life has become more desirable with cleaner air. Conversely, in cities where photochemical pollution has increased, the annoyance of its presence has risen proportionately.

Certainly there can be no negative biological consequences of cleaner air *per se*. The only negative aspects are of an economic or social nature as one questions if the values of clean air are worth the costs. Yet, some of the costs of control have perhaps been overemphasized. Few of the economic fears once expressed actually have been realized. There are infrequent examples of industries having been shut down or jobs having been lost, but many jobs have been added to maintain the new pollution control equipment. Industries have not moved out of the country or relocated to areas of less stringent controls, although some of this may be attributed to variances and delays obtained in effecting control programs.

The most serious impact has been more subtle in the increased costs of products because of the added capital and operating costs of control. This includes higher consumer prices for metals and automobiles and higher power rates, but these probably comprise only a minor part of the constantly rising costs of labor, plus a general inflation throughout the world.

It has sometimes been argued that power rates from further pollution controls may rise to a level where the poor cannot afford electricity, but this, too, seems invalid in view of the general costs of inflation and the comparatively minor costs of pollution control.

Theoretically, a degree of pollution control might be attained where the benefits did not justify the costs. Certainly this could readily be reached in the nonindustrial countries, where controls might comprise a larger segment of their GNP. In the United States, however, the costs of control have yet to inflict a noticeable burden, and the costs of achieving primary air quality standards seem well justified. The economic costs of achieving secondary standards might be more difficult to justify, and achieving some of the still more rigid state standards even less rewarding either economically or socially. After all, standards are intended to 'protect' human welfare." This includes economic as well as biotic welfare. It would seem that there are more socially redeeming ways to spend hundreds of millions of dollars then to remove the final percentage of sulfur from industries' furnaces. The concentrations still emitted are usually well below the threshold injurious to plants and still further from that injurious to man. We are now talking about the esthetic reward of improving visibility and the principle of internalizing the costs of production. No doubt these values should also be considered, but they represent a less tangible monitory cost.

Applying the same ideals to transportation, we should consider the costs and consequences of removing all the exhaust emissions from the automobile. A better approach would be to change the technology of the engine or increase the desirability of mass transit, thus avoiding the adverse qualities of control.

In conclusion, the biological consequences of not achieving environmental controls is reasonably well documented, at least for plants, although the costs are not well established. Effects on human health are more obscure. Threshold values are still being sought, but in many cases seem to be much higher than permitted by the secondary air quality standards. If they could be attained, health of both plants and man would be protected. It seems they can and are being achieved around industry, but chances of achieving them where automobiles provide the major source of pollution are more remote.

When and if they are attained, no direct adverse biological consequences can be fore-

seen, but the economic and social costs must not be ignored. Also, some natural pollution will always be with us. This alone may sometimes be sufficient to exceed even the primary air quality standards, especially in the world's overgrazed rangelands.

Another aspect, not fully considered, is the long-distance transport of pollutants. The United States is far ahead in cleaning the air. Pollutants from other industrial and developing countries may be with us for many decades. The degree to which such pollutants contribute to our own air sheds is not known. Perhaps these foreign sources, plus the natural background pollution, raises some question as to the amount of money that should be spent to achieve almost "pure" air on a national basis.