Ozone Depletion Would Have Dire Effects

Academy panels predict increased incidence of skin cancer, decreased agricultural output if chlorofluoromethane release continues

Depletion of the earth's ozone layer resulting from the release of chlorofluoromethanes into the atmosphere may have substantial health and environmental effects, according to a new report from the National Academy of Sciences. Increased ultraviolet radiation transmitted through the stratosphere as a result of the depletion may produce large numbers of new cases of skin cancer, reduce the productivity of agricultural crops, destroy larval forms of some marine life, and produce a slight warming of the earth's atmosphere. Alternatives are available for many of the uses of the chemicals, the report says, but "further unilateral U.S. action can have only a limited impact in reducing the extent of global stratospheric ozone depletion."

The new report,* issued just before Christmas, is the second report on chlorofluoromethanes (CFM's, also known as chlorofluorocarbons or by the trade name Freons) issued by the Academy in the last 2 months of 1979. The first, issued in November by the Academy's Panel on Stratospheric Chemistry and Transport (*Science*, 7 December 1979, p. 1167), projects that there will most likely be a 16 percent reduction in the concentration of ozone in the stratosphere if CFM's continue to be released at the 1977 rate. The new report, prepared by two other panels, explores the effects of such a reduction in ozone and considers ways to reduce the use of CFM's.

Stratospheric ozone is important because it screens out most of the so-called damaging ultraviolet (DUV) radiation—light with wavelengths between 290 and 320 nanometers—emitted by the sun. A 16 percent reduction in stratospheric ozone will produce a 44 percent increase in the amount of DUV radiation reaching the earth's surface, and a 30 percent reduction in ozone will double DUV radiation. The potential hazards of such an increase were considered by the Committee on Impacts of Stratospheric Change, chaired by John W. Tukey of Bell Laboratories.

The most important health effect of DUV radiation is the induction of skin cancer. There are two principal types of skin cancer, melanoma and nonmelanoma. Nonmelanoma skin cancer is the most common form of cancer, and its incidence in the United States is variously estimated to be between 300,000 and 600,000 cases per year. Nonmelanoma skin cancers can generally be removed by simple surgery and are rarely fatal, accounting for only about 1600 deaths per year in this country. Nevertheless they can cause substantial disfigurement of the victim. Nonmelanoma skin cancer usually develops on parts of the skin normally exposed to direct sunlight, and its incidence is correlated with cumulative lifetime exposure to DUV radiation.

Melanoma is a more severe form of skin cancer that is fatal nearly a third of the time. The U.S. incidence in 1979 is estimated at about 13,600 cases, and the number of deaths at about 4,000. The relationship of melanoma to DUV radiation is more complex than that of nonmelanoma skin cancer, but the incidence of melanoma has been increasing at an annual rate of about 3 percent in recent years, presumably as a result of greater voluntary exposure to sunlight. The greatest incidence of melanoma occurs among individuals who do not tan readily, particularly those in this group, such as white-collar workers, who are exposed to the sun only intermittently.

The committee concludes that the incidence of both types of skin cancer will increase sharply if there is an increase in DUV radiation. In the United States alone, a 16 percent reduction in stratospheric ozone would lead to "a certainty of very many thousands of additional cases every year" of nonmelanoma skin cancer and "a likely probability of thousands of new cases a year" of melanoma, of which a substantial fraction would be fatal.

It is much more difficult to predict with certainty the effects of increased DUV radiation on plants and animals, primarily because there is simply not enough experimental foundation. DUV radiation damages DNA in all types of cells, whether plant or animal: it is the degree of susceptibility to this damage that is at question.

More than 100 varieties of agricultural crops have been exposed to increased DUV radiation in controlled environment growth chambers—82 of them by Robert H. Biggs and Susan V. Kossuth of the University of Florida at Gainesville. Biggs and Kossuth found that approximately 20 percent of the varieties are sensitive to daily doses of DUV on the order of those delivered by Florida sunshine at present ozone concentrations. Increased exposure of these plants to DUV radiation led to reductions in the dry weight of the plant and changes in the proportion of plant material represented in roots, shoots, and leaves. Another 20 percent of the varieties were resistant to four times as much DUV as the present level, while the remainder showed intermediate sensitivity.

These apparently straightforward results become much more ambiguous, however, when plants growing in open fields are subjected to increased DUV radiation from lamps. Such experiments have so far been carried out on only about 15 plant species, and the results are hard to interpret because growth variations under field conditions often obscure responses to specific treatments. In most cases, plants grown in the open field appear more resistant to DUV than plants grown in a controlled environment; in a few cases where direct comparisons are possible, they are as much as four times more resistant. Nonetheless, some species, including sugar beets, tomatoes, mustard, and corn, do exhibit lower yields when exposed to increased DUV radiation. The committee thus concluded that a 16 percent reduction in ozone "might cause an appreciable reduction in yield for at least a few crops."

Another area of concern is the aquatic ecosystem. Studies on more than 60 aquatic microorganisms, protozoa, algae, and small invertebrates by, among others, John Calkins and his colleagues at the University of Kentucky indicate that most are sensitive to current water surface levels of DUV radiation. The potential for hazard is still speculative, however, since little is known about either attenuation of DUV by water or the normal depths at which the organisms spend most of their time.

John R. Hunter and his associates at the National Marine Fisheries Service in La Jolla, California, have found that the commercially important anchovy normally exists near its UV tolerance limit. A 16 percent reduction in ozone

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would, the committee concludes, "as a 'worst case,' kill over 50 percent of the anchovies in the top 10 meters of the clearest ocean water or else would require them to adjust their usual water depth to diminish UV exposure," with unknown consequences. Similar studies of crab and shrimp larvae show that they, too, are near their DUV tolerance limit. The overall sampling of marine species is still very small, however.

Another potential effect of continued release of CFM's is a change in climate resulting from both direct and indirect effects. The CFM's can themselves affect climate by absorbing infrared radiation given off by the earth's surface, thereby contributing to the so-called greenhouse effect that leads to atmospheric warming. A CFM-induced reduction in stratospheric ozone will also, through a complicated series of events, most likely produce atmospheric warming. The net effect of continued release of CFM's at the 1977 rate, the committee predicts, will be an average warming of the earth's surface by a few tenths of one degree Celsius, or about 10 percent of the warming that is predicted to result from increased combustion of fossil fuels.

The second half of the new report was produced by the academy's Committee on Alternatives for the Reduction of Chlorofluorocarbon Emissions, chaired by Max S. Peters of the University of Colorado. This group makes a strong case that global cooperation is necessary to ameliorate the potential hazard from CFM's. Since the United States banned the use of CFM's in most aerosol spray cans, this country's share of world output of CFM's has dropped from half to about a third. Further unilateral action by the United States can have little effect, particularly since use of CFM's elsewhere is increasing and new uses that take advantage of their inertness continue to be found. The greatest global gain, the committee contends, would result from the worldwide elimination of nonessential aerosol propellant uses. Experience in the United States has already shown that the economic impact of such an action would be small.

Beyond such a ban, however, control becomes much more difficult because the versatile chemicals have found their way into so many different applications and sometimes appear virtually impossible to replace. CFM's are ideal for commercial refrigeration and air conditioning systems, for home refrigerators and freezers, and as a solvent for cleaning electronic components. No one has yet found an acceptable alternative for such applications. CFM's will also be difficult to replace as blowing agents for the rigid polystyrene and polyurethane foams used for insulation and other purposes. Most of the CFM used to form air cells in these foams remains trapped in the foam throughout its life and contributes substantially to the insulating value. Insulating foams produced with other blowing agents are not nearly as effective.

Significant improvements can be made. The CFM's in automobile air-conditioners, for example, are routinely replaced every 1 to 2 years, Peters says, primarily because of leakage. Design and construction modifications that would minimize such leakage could yield significant reductions in CFM emissions at a relatively low cost. Improved recovery and recycling of the refrigerants during servicing of automobile air-conditioners could also yield significant reductions in emissions, but this would be much more expensive to implement since there are such a large number of service facilities.

Greatest global gain would come from elimination of aerosols.

CFM's are also used as the blowing agent for soft polyurethane foams, such as those used in seat cushions, fabric backing, and the like. Nearly all of this CFM is released into the atmosphere shortly after the foam is formed. Given a few years to adjust properties and processes, the committee says, the industry could replace virtually all of this CFM with methylene chloride, with only a small loss in cushioning properties.

Other applications for which some alternatives to CFM's are available include metal cleaning and drying, solder flux removal, garment cleaning, industrial sterilization of medical equipment, and fast freezing of food. In each case, though, there is an economic incentive to remain with CFM's, and it will probably be necessary to develop a regulatory incentive to encourage change.

The panel considered a large number of ways in which use of CFM's could be controlled, and concluded that no one strategy would be effective for all uses. Instead, a combination of approaches will be necessary and their use will rely more on political and economic decisions than on scientific rationale. Among the possibilities:

▶ *Bans.* It is probably impossible to ban all uses of CFM's, but certain uses, such as aerosol propellants, can easily be prohibited.

▶ *Control technology standards.* It is possible to require the use of the "best available technology" for reducing emissions, including containment, recapture, and recycling in industrial and manufacturing operations. Such an approach would be expensive and hard to enforce.

▶ *Taxes on production and use.* This approach could work when more expensive or less effective alternatives are available, but the tax would simply be passed on to the consumer if no acceptable alternatives were available.

▶ *Quotas implemented by marketable permits.* The government might specify overall ceilings for production or use, allowing firms to buy and sell "rights" among themselves.

▶ *A deposit-refund system.* The purchase of a refrigerator, for example, might require a $50 deposit for the CFM's it contains; the deposit would be refunded when the refrigerator was turned in at a recycling center at the end of its useful life.

▶ *Recycling on disposal.* The government might, for instance, require and subsidize collection centers for refrigeration equipment.

Notably missing from the list are point source emission standards and "safe" disposal standards. The former were rejected because CFM emissions at a factory are difficult to monitor directly and any alternative would be prohibitively expensive. The latter were rejected because—aside from pyrolysis, which is both "expensive and polluting"—there are no feasible methods for "denaturing" CFM's or containing them in perpetuity. The only immediately practical disposal option is recycling.

Both of the Academy reports appear to be falling on deaf ears. A report from the United Kingdom's Department of the Environment issued in 1979, and typical of governmental attitudes around the world, concluded that "present understanding of ozone depletion is limited and based on model assumptions which have not been adequately identified." The fluorochemical industry itself calls the whole subject "hypothesis" and is asking for another 4 years without regulatory action to obtain conclusive scientific data. (Three years ago, the industry asked for only 3 years to obtain the data.) But the scientists who have prepared the two Academy reports are convinced that the "hypothesis" is correct and that stratospheric ozone is being destroyed by CFM's. Further delay, they argue, will merely increase the eventual problems.—THOMAS H. MAUGH II