The Threat to Ozone Is Real, Increasing

Academy group affirms that chlorofluorocarbons do reach stratosphere, are dissociated by sunlight, and do react with ozone

The potential for depletion of ozone in the stratosphere caused by the release of chlorofluorocarbons is greater than had previously been predicted, according to a new report from the National Academy of Sciences.* The report projects that continued production and release of the chemicals at the 1977 rate will lead to an eventual 16.5 percent depletion of stratospheric ozone, a little more than twice the depletion projected in a 1976 report by the same panel. Continued growth in production of certain other halocarbons will exacerbate the problem, the panel says, even though a significant proportion of these materials is destroyed in the lower atmosphere. Growth in production and use of chlorofluorocarbons, which is expected to occur if controls are not established in countries other than the United States, will lead to major disturbances of the stratosphere.

The two most important chlorofluorocarbons (which are also known as chlorofluoromethanes, CFM's, or by the trade name Freons) are trichlorofluoromethane (CCl_3F) and dichlorodifluoromethane (CCl_2F_2). Their potential for harming the stratosphere was first suggested in 1974 by F. Sherwood Rowland and Mario Molino of the University of California at Irvine. They postulated that since the CFM's are almost completely inert in the lower atmosphere, they would eventually all make their way to the stratosphere, where they would be dissociated into their constituent atoms by sunlight. The chlorine atoms thus released could then act as a catalyst in a complicated series of reactions that would have the net effect of converting some of the ozone in the stratosphere into oxygen.

Since stratospheric ozone filters out most of the ultraviolet radiation in sunlight, a decrease in its concentration would permit more ultraviolet radiation to reach the earth's surface. This increase is expected to have an adverse effect on animals, plants, and climate. Another academy report, expected early in 1980, will discuss what these effects might be.

Rowland and Molino's hypothesis was initially scoffed at, but a great deal of laboratory work, measurement of the concentrations of various species in the stratosphere, and computer modeling of the atmosphere have failed to find any significant holes in it. The 1976 academy report (*Science*, 8 October 1976, p. 170) concluded that continued release of CFM's at the 1973 rate—which is within 5 percent of the rate in 1977—would lead to an eventual 7.5 percent reduction in stratospheric ozone. A 1977 report by the National Aeronautics and Space Administration used eight different models of the atmosphere to project depletions ranging from 10.8 to 16.5 percent. The estimate in the new report is based on refinement of the previous models and new values for selected rate constants.

The chief reason for the increased depletion projected in the new report is direct measurement of several key rate constants that had previously been obtained only indirectly. In particular, it was found that the rate constant for the reaction of nitric oxide with peroxide ($NO + HO_2 \rightarrow NO_2 + OH$) is about 40 times as large as was previously thought. Several other rate constants were also revised when measured directly. When these new values were incorporated into the atmospheric models, an eventual ozone depletion of 18.6 percent is projected if production and release of CFM's continues at 1977 rates. Such a change in concentration would alter the amount of water that reaches the atmosphere; explicit consideration of these changes reduces the most probable value to 17.7 percent.

To take into account any potential sinks for CFM's that might exist in the lower atmosphere, the panel "rather arbitrarily" further reduced the most probable value to 16.5 percent. This action was taken to reflect the possibility that CFM's adsorbed onto desert sands might be dissociated by sunlight. The potential for this dissociation has been demonstrated in the laboratory, but the process appears to be much slower than diffusion of CFM's into the stratosphere. There are no other known atmospheric sinks for CFM's and a crude balance of production totals with the amount of CFM's known to be in the atmosphere suggests that none will be found. The panel also thinks it unlikely that any other gross changes in reaction rates will be necessitated by new data.

Confirmation of the hypothesis by actual measurement of ozone depletion in the stratosphere is still far in the future, the panel concludes. Because of natural variations in stratospheric ozone concentrations, a 4 to 5 percent reduction caused by CFM's must occur before it can be detected reliably. The current depletion is estimated to be about 2 percent and a 5 percent depletion is not expected until the year 2000. If all production of CFM's were halted after such a depletion was observed, the eventual total depletion would be about 7 percent.

World production of CFM's has dropped to pre-1973 levels, primarily as a result of the U.S. ban on their use in aerosol sprays. But production outside the United States has actually been increasing. Regulatory agencies in other countries continue to accept the industry position that there remain major uncertainties in a number of key assumptions in the theory, that there have been some discrepancies between measured concentrations of reactants in the stratosphere and calculated values, and that there are still no proven, safe alternatives to CFM's for many applications.

One recent study predicts that, in the absence of further regulatory actions, world production of CFM's will grow at an annual rate of 7 percent between 1980 and 2000. If production figures based on this estimate are put into the model, the panel concludes, the projected depletion is nearly 57 percent. The changes in the stratosphere caused by such a depletion would be so great, however, that the model for atmospheric transport would no longer be valid; the eventual depletion would reach at least 30 percent, though.

The models on which the panel based its conclusion do not include any deple-

*"Stratospheric Ozone Depletion by Halocarbons: Chemistry and Transport" (National Academy of Sciences, Washington, D.C., 1979). The chairman of the panel is Harold I. Schiff of York University.

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tions from other halocarbons even though these are a source of concern. The use of chlorodifluoromethane ($CHClF_2$), particularly in refrigeration, has increased 25 percent in the past 2 years, and the production of methylchloroform (CH_3CCl_3), widely used as a degreasing solvent, is doubling every 5 years. These chemicals are less inert than CFM's and are largely destroyed in the lower atmosphere, but significant quantities can make their way to the stratosphere. Atmospheric measurements, the panel says, now indicate that methylchloroform contributes between a quarter and half as many chlorine atoms to the stratosphere as either trichlorofluoromethane or dichlorodifluoromethane. If its usage continues to grow, it may become the largest single source of stratospheric chlorine. Once in the stratosphere, methylchloroform is not as effective as the CFM's in destroying ozone, but the differences are so small that the continued growth of its production remains a major cause for alarm.

—THOMAS H. MAUGH II

Plants: Can They Live in Salt Water and Like It?

Finding out how plants cope with stresses such as salt and drought may eventually permit the development of more resistant strains

Irrigation of farm crops is turning out to be something of a mixed blessing. It permits farming in climates that would otherwise be too dry to support agriculture. But in many areas irrigation is leading to the degradation of the soil because of the deposition of such high concentrations of salt that plants can no longer be grown there. "Salinity is now recognized as a significant problem in one-third of all irrigated land," said Jack Norlyn of the University of California, Davis, at a recent conference* dealing with plants and how they cope with environmental stress.

The conference participants focused mainly on the interrelated stresses of salinity and drought. Many agricultural scientists think that arid and semiarid lands may be the best bet for increasing our supply of arable land. "The arid and semiarid regions impose the worst stress," says Emanual Epstein, also of Davis, "but they are the most promising regions for increasing our production of food and fiber." The soil is often fertile, sunlight is plentiful, and the growing season is long. The only thing that prevents many deserts from blooming is lack of water.

Irrigation can solve that problem—provided a supply of fresh water is available—but the solution is only temporary unless the irrigation is very carefully managed to prevent accumulation of salt. For example, the water delivered each year in California, 90 percent of which ends up on agricultural lands, contains 10 million tons of salt, according to James Walsh of the California Department of Water Resources. Moreover, the situation is often aggravated by the fact that many arid soils have a high salt content to start with.

Unless drainage is provided to carry off the irrigation water, the water with its dissolved salt sinks deep into the soil. Then, if the water table rises, as it periodically does, the salt is carried back to the surface, where it can reduce plant growth and crop productivity. Evaporation of irrigation water also contributes to the salinization process. The increasing salinity of the San Joaquin Valley of California is already costing the farmers there $32 million per year in reduced crop yields.

The problem of dry or saline soils might be circumvented if plants more tolerant of these conditions could be developed, although some agricultural scientists have questioned the wisdom of this approach. In their view, better management of irrigated lands to prevent salt deposition and reclamation of lands where it is already a problem are preferable. But, as Norlyn points out, development of salt-tolerant plants might permit expansion of agriculture into lands that are not now usable because of their high salt content. He suggests that barley would be an especially good candidate for such improvement because it is already relatively salt-resistant and a small improvement may make it possible to grow barley in currently marginal lands. The increasing demands of a growing world population for food and energy may necessitate an expansion of arable land, especially if biomass, which is plant material, ever becomes an important energy source.

The methods under consideration for developing salt-tolerant plants range from the commonplace, those using established practice to select and breed plants capable of thriving in salty environments, to the exotic, namely, genetic engineering. Some observers thought that the conference title, which stressed the genetic engineering of osmoregulation, was premature, if not presumptuous, however. (The term osmoregulation denotes the strategies that plant and bacterial cells may adopt to prevent the water loss, a cellular injury caused by some stresses, including salinity, drought, and cold.)

Any scientist who wants to be a genetic engineer must first catch the appropriate genes. And plant researchers have yet to do that for osmoregulation. As C. Barry Osmond of Australian National University in Canberra put it, "As far as genetic engineering goes, we do not know what we want to engineer at the moment."

This criticism notwithstanding, the conference participants pointed to some recent developments that lead them to believe that they are on the right track. For example, Lászlό Csonka and Raymond Valentine of the University of California, Davis, have generated a mutation that confers salt tolerance on bacteria.

When bacteria, or plants for that matter, that are not tolerant to salty conditions are placed in an environment with a high salt concentration, their cells tend to lose water. This happens because the water concentration inside the cells is higher, or the osmotic pressure lower, than that outside. Consequently, water flows out of the cells down the concentration gradient.

Some plants—those that live in the sea

*Symposium on Genetic Engineering of Osmoregulation: Impact on Plant Productivity for Food, Chemicals, and Energy, held at Brookhaven National Laboratory, Upton, New York, 4 to 7 November 1979. The symposium was sponsored by the National Science Foundation and the Department of Energy.