Ozone Destruction: Problem's Scope Grows, Its Urgency Recedes

Evidence of stratospheric pollution by chemicals capable of reducing the earth's ozone shield continues to accumulate. Recently released figures confirm that oxides of nitrogen (NO_x) from high-altitude jet aircraft, for example, are a potential hazard. In addition to sources of free chlorine identified earlier, primarily chlorofluoromethanes used as spray can propellants and refrigerants (*Science*, 25 October 1974, p. 335), it now appears that carbon tetrachloride (CCl_4) and methyl chloride (CH_3Cl) are present in the atmosphere and may also contribute free chlorine to the stratosphere. Still under study is a catalytic agent that is potentially even more destructive of ozone than chlorine or NO_x, namely, free bromine.

The dimensions of the problem and the scope of the threat to living things have yet to be fully established. Not all the potential pollutants are clearly of human origin (CH_3Cl, for example). Predictions of the ozone destruction to be expected from a given concentration of pollutants are being revised downward on the basis of new laboratory measurements. But the laboratory studies and new high-altitude sampling have tended on the whole to support, if not completely confirm, the photochemical models on which calculations are based. And it is thus increasingly likely that the potential for release of chlorine and other species into the stratosphere will impose very real limits on human use of certain chemicals and technologies, limits that are global in extent and not far in the future.

Point in the Fine Print

One such limit emerges from the fine print of the Department of Transportation's report on stratospheric pollution by aircraft.* The report summarizes the results from the 3-year Climatic Impact Assessment Program that has produced much of the existing data on stratospheric effects. Emphasis in the report is given to the determination that supersonic transports (SST's) already in production (perhaps 30 British-French Concordes and Russian TU-144's) will cause no detectable diminution of ozone, rather than to the discussion of the effects of more widespread aircraft operations in the stratosphere. Critics of the report have charged that this emphasis not only distorts the research findings, but that it is closely tied to the Federal Aviation Administration's recently revealed plans to permit regularly scheduled service of the Concorde between Europe and the United States. Whether or not Concorde flights will eventually generate new momentum for a U.S. competitor, as some observers believe, the report does reflect an assumption widely held in the U.S. aviation industry—that, notwithstanding congressional decisions, and gloomy economic prospects to the contrary, there will eventually be a U.S. supersonic fleet.

There seems, in any case, to be little doubt that emissions of NO_x from SST's and even, to some extent, from subsonic aircraft, can cause a reduction in the concentration of ozone in the stratosphere. It is possible to calculate from information given in the report that, with current jet engines, a 500-airplane fleet of "advanced SST's" would lower ozone concentrations over the Northern Hemisphere by about 8.7 percent. A 20-fold reduction in engine emissions of NO_x would be required to limit the ozone decrease to 0.5 percent for such a fleet. Even subsonic aircraft, if they were to fly at greater altitudes, could have a sizable effect. A fivefold expansion in the number of wide-body jets such as the Boeing 747 (about 230 are currently in operation at a mean altitude of 11 kilometers) flying 2.5 kilometers higher would by themselves cause nearly a 1 percent ozone reduction. The report is optimistic about the chances for improving SST engines to reduce NO_x emissions sixfold over a 15-year period and proposes a $50 million program to accomplish this.

Polluting technology is easier to turn off than the effects of chemicals that, once released, are removed from the atmosphere only by natural processes and, in the case of halomethanes, very slowly. New measurements confirm that chlorofluoromethanes do penetrate high into the stratosphere. Philip Krey of the Energy Research and Development Administration's Health and Safety Laboratory in New York City found Freon-11 ($CFCl_3$) at concentrations of about 60 parts per trillion (ppt) in the lower stratosphere, a result consistent with earlier measurements; at about 19 kilometers, the concentration had dropped to about 20 ppt. The falloff with altitude is consistent with the postulated decomposition of the molecule by ultraviolet radiation, with the release of free chlorine, at about 30 kilometers. The air samples, gathered with high-altitude aircraft at a variety of latitudes, also contained Freon-12 (CF_2Cl_2) and traces of CCl_4.

Halomethanes Increasing

The amount of halomethanes in the atmosphere appears to be increasing. Peter Wilkniss and his colleagues at the Naval Research Laboratory in Washington, D.C., compared shipboard and aircraft measurements of $CFCl_3$ in the lower atmosphere from 1971 to 1974, and they report an increase of about 67 percent over the period. They estimate that world production of this chemical also increased rapidly during this period, a finding which they believe suggests that it rapidly enters the atmosphere. Wilkniss has measured CCl_4 in the lower atmosphere and believes that concentrations of this species have also increased in recent years, although there are greater variations and greater uncertainties in the date.

According to calculations with models of the photochemistry and transport processes in the stratosphere, the halomethanes already present in the atmosphere are sufficient to decrease ozone concentrations somewhat. (Seven different investigations, with a variety of models, all draw similar conclusions.) But the amount of the decrease is being revised downward as more accurate chemical data are fed into the models. Laboratory studies by Douglas Davis and Robert Watson at the University of Maryland have shown that rate constants for two of the reactions in the chlorine chemistry cycle were in error by factors of 1.6 and 2, with both errors such as to overstate the ozone decrease. Uncertainties as high as a factor of 5 are still present in the rate constants for formation and destruction of chlorine

* A. J. Grobecker *et al.*, *The Effects of Stratospheric Pollution by Aircraft* (Climatic Impact Assessment Program, Office of the Secretary of Transportation, Washington, D.C., 1974).

oxides, however. They have also ruled out a number of other possible reactions, particularly one process (combination of HCl with ammonia) that has been suggested as a possible chemical sink for HCl. Their results indicate that transport of HCl to the lower atmosphere could be the main means of eliminating chlorine from the stratosphere. The net result is not to make the problem go away—indeed, if anything, the new data strengthen the assumptions in the models—but to suggest that it is not as urgent as was first believed.

Preliminary results from one updated model give some measure of the time scales and magnitudes involved. Paul Crutzen of the National Center for Atmospheric Research (NCAR) calculates, for example, that halomethanes in the atmosphere have already reduced ozone concentrations by about 0.5 percent. If halomethane production were halted in 3 years, the ozone depletion would climb from about 0.7 percent in 1978 to a maximum of about 1.7 percent in 1990 before leveling off, only slightly higher than would result from an immediate cutoff. These new estimates, as a result of the rate data of Watson and Davis, are about a factor of 2 smaller than his earlier estimates. Crutzen cautions, however, that these are minimum values, since the effects of CH_3Cl and CCl_4 could increase ozone depletion substantially.

Additional support for the models comes from measurements of HCl in the stratosphere, which agree with model predictions. Allan Lazrus of NCAR found evidence of HCl at concentrations as high as 500 ppt in samples collected up to 27 kilometers. William Sedlacek of the Los Alamos Scientific Laboratory analyzed the same samples by a different method with the same results. The most striking feature of the data is that the HCl concentration increases with altitude, a distribution consistent with the idea that this material is the sink for stratospheric chlorine as predicted by photochemical models.

High Concentration of CH_3Cl

A puzzling finding is the high concentration of CH_3Cl measured in the lower atmosphere near Pullman, Washington, by R. A. Rasmussen of Washington State University—as high as 530 ppt. Similar atmospheric concentrations have been detected by James Lovelock of Reading College in England, who has also found CH_3Cl in seawater at concentrations of about 3000 ppt.

The sources of CH_3Cl have been a subject of considerable speculation. Several halomethanes, including CH_3Cl and chloroform ($CHCl_3$), are reported to be formed in the treatment of sewage with chlorine and even in the process of chlorinating fresh water supplies. Other industrial uses of chlorine are also potential sources. Some investigators believe that these compounds, escaping into the atmosphere, account for the observations. Others believe that the high concentrations of CH_3Cl imply a nonanthropogenic origin and, possibly, the existence of a natural chlorine cycle in the stratosphere.

Methyl chloride and other halomethanes with a carbon-hydrogen bond are not as chemically inert as the chlorofluoromethanes, and their lifetimes in the atmosphere are not expected to be as long. But if CH_3Cl does indeed reach the stratosphere (no measurements have been reported), it might be a major source of stratospheric chlorine. A key measurement to make, according to Davis, will be the atmospheric concentration of hydroxyl radical (OH^-), which decomposes CH_3Cl; he and his colleagues have developed a laser-induced fluorescence instrument for that purpose.

Another catalyst capable of destroying ozone, one now receiving increased attention, is free bromine. Bromine undergoes photochemical cycles similar to those of chlorine, according to

Speaking of Science

Public Credibility on Ozone

The discovery of a new environmental problem unfortunately often brings with it both claims of imminent disaster and bland denials that the problem exists at all. Two recent examples in connection with the ozone problem are worthy (if that is the word) of note.

The press release and summary report issued by the Department of Transportation (DOT) in connection with the Climatic Impact Assessment Program (see accompanying story) can only be described as misleading, whether deliberately or not. The authors of that report have added to the confusion by not immediately correcting press reports which headlined precisely the reverse of the principal research finding. "Scientists clear the SST" was the way the *Christian Science Monitor* put it; the fact is that SST's in large numbers, in the opinion of the scientists who did the research, do pose a threat to the ozone layer. The result has been, temporarily at least, to publicly discredit those scientists who initially raised a quite justified concern about SST's and to raise a credibility gap in regard to the still more serious threat of ozone depletion by halocarbons and other chemicals. Thus the report and DOT's public stance on the environmental effects of SST's, while not a bland denial, amount to nearly the same thing.

Alarmist statements have had their share of exposure as well. Warnings that continued use of halomethanes "could drive life on earth back to where it was hundreds of millions of years ago," calls for an immediate ban on halomethane production because "the danger is too great to wait even a single year," and scare statements about the possible use of bromine as an ozone-destroying weapon have been made publicly and, not surprisingly, have found their way into press accounts. These statements are incautious, to say the least, in view of the uncertainties still attached to the calculations and assumptions on which they are based. Ironically, the eastern university scientists who made them have also played major roles in discovering and documenting the vulnerability of the ozone layer to human activities—in establishing, in other words, that there is a real ozone problem. Whether alarmist statements can be attributed to what one scientist described as "the smell of a Nobel Prize" or simply to poor judgment, they have not served to increase the credibility of a serious problem.—A.L.H.

Watson, but it has an additional set of ozone-destroying reactions that, unlike those involving chlorine or NO_x, can proceed at night and at lower altitudes. Moreover, bromine does not readily form the catalytically inactive species hydrogen bromide (HBr, analogous to HCl in the chlorine cycle). The result is that bromide is, molecule for molecule, a more efficient catalyst than chlorine and would be a source of considerable worry if it were to be present in the stratosphere in any appreciable quantity.

Only a few measurements of bromine compounds in the stratosphere have been made. Sedlacek, for example, finds bromine at concentrations between 7 and 12 ppt. This concentration of bromine, if it is in the form of HBr, is consistent with calculations by Michael McElroy and Steven Wofsy of Harvard University which suggest that bromine may cause a 0.5 percent reduction in the ozone concentration at present. They propose that methyl bromide (CH_3Br), widely used to fumigate agricultural land, is the source of the stratospheric bromine. Other investigators doubt that CH_3Br actually reaches the stratosphere.

The lack of any demonstrated hazard from bromine, however, does not reduce the need for a more careful scrutiny of how, and in what form, bromine and chlorine are used in human activities. Indeed, it is likely that understanding and coming to grips with the vulnerability of the earth's ozone layer to human activities has only just begun.

—ALLEN L. HAMMOND

Thymic Hormones: Inducers of T Cell Maturation

People who lack normal T cells are in a lot of trouble. This is dramatically illustrated by the case of Heather, a 5-year-old girl who suffers from thymic hypoplasia, that is, a poorly developed thymus gland. The thymus is necessary for the normal differentiation and maturation of T (for thymus-derived) cells. In May of last year, Heather's T cell count was well below normal, and she was near death from the infections that her inadequate immune system could not fight off.

Because all other therapies had failed, Heather's physicians decided to treat the girl—the first patient to be so treated—with thymosin, a hormone preparation made from bovine thymus glands. Heather's T cell count increased. Today, with continued therapy, she is leading a virtually normal life. Moreover, investigators also have evidence that thymosin deficiency may be associated with a number of diseases besides thymic hypoplasia. They include some additional immunodeficiency diseases, certain autoimmune conditions, and cancer.

Cell-mediated immunity requires T cells, also called T lymphocytes. The graft-versus-host reaction, transplant rejection, immune surveillance of tumor cells, delayed hypersensitivity to foreign antigens, and resistance to viruses all depend on this portion of the immune system. In addition, T cells aid in the regulation of humoral immunity, which is the province of B (for bone marrow) cells, the second class of lymphocytes.

When properly stimulated by antigens, B cells differentiate into antibody-secreting cells called plasma cells. Antibodies act on a number of antigens, including bacteria and viruses. Helper T cells are needed for synthesis of many antibodies, whereas another functional class of T cells, the suppressor T cells, may repress antibody production.

Some T cells mature within the thymus itself, but there is evidence that others need not enter this gland in order to differentiate. One way that the thymus effects the maturation of T cells is through the secretion of a hormone or—more likely—hormones. About 10 years ago, when they were both working at Albert Einstein Medical College, Allan Goldstein, now at the University of Texas Medical Branch in Galveston, and Abraham White, currently at Stanford University School of Medicine, discovered thymosin. Goldstein now supplies the thymosin preparations to Heather's physicians, Arthur Ammann and Diane Wara of the University of California Medical School in San Francisco, and also to most other investigators studying the action of the hormone. The material that has been used for these investigations is a partially purified preparation designated thymosin fraction 5 but often simply called thymosin.

Found in Several Species

Although Goldstein and his colleagues have identified thymosin in a number of species, including the mouse, rat, rabbit, and human, they usually extract the hormone from bovine thymus. Thymosin activity does not appear to be species-specific. The Galveston group has recently purified a single active component (thymosin fraction 8) from fraction 5. It is a polypeptide containing about 108 amino acids and weighing 12,200 daltons. Residues of glutamic and aspartic acids, the acidic amino acids, constitute about 50 percent of the molecule.

There are indications that fraction 5 may contain more than one active component. It contains at least 11 other acidic polypeptides, weighing from 1,200 to 14,000 daltons, in addition to the one purified. Goldstein said that this latter material may be less active in some assays than the less pure fraction 5. This could mean that active components have been lost during purification or that the procedures have altered the material with consequent loss of activity.

Administration of thymosin fractions can substitute, at least partially, for a functional thymus gland. Ammann said that weekly injections of thymosin fraction 5 have maintained Heather's T cell count at a near-normal level and have corrected some of her deficient immune reactions; others remain unchanged, however.

Bovine thymosin preparations also alleviate immunodeficiencies in mice. Thymectomized newborn mice usually die from infections and a wasting disease. Goldstein and his colleagues found that partially purified thymosin preparations reduce the incidence of wasting disease and death in such animals and partially restores their cell-mediated immunity. Thymosin administration to newborn mice accelerates the development of their T cell functions. The animals can resist the growth of virus-induced tumors, and their spleen cells, when injected into mice of another genetic type, can mediate a graft-versus-host reaction at an earlier age than normal. (The spleen stores T lymphocytes.)