Chlorine and Ozone—CFCs

Chlorofluorocarbons (CFCs), invented in 1928, have been used for a variety of purposes including refrigerants, air conditioner coolants, aerosol propellants, foam packaging fillers, and computer cleaning agents. Since the mid-1980s, numerous studies and reports have documented that the protective ozone shield in the stratosphere was being depleted. Speculation concerning the widespread release of chlorine, in the form of chlorinated fluorocarbons, quickly surfaced, and by 1991 the connection between ozone depletion and chlorine had been established. Antarctic ozone depletion reached record levels in 1993 when the average size of the hole in the ozone layer extended over an area measuring approximately 8.5 million square miles. (The 1-day peak size of the Antarctic ozone hole was 10 million square miles, reached on September 7, 1996.)

Scientists have also documented ozone depletion in mid-latitude regions. The National Aeronautics and Space Administration's Stratospheric Photo Chemistry, Aerosols, and Dynamics Expedition Project launched nine flights into the mid-latitude stratosphere during 1993. Those flights measured the concentration of ozone, aerosol particles, nitrogen oxides, hydrogen oxides, and CFCs, among other compounds. Results confirmed ozone thinning at altitudes of up to 12 miles. While depletion in such regions does not result in the large hole characteristic of the Antarctic, estimates of a 4 percent loss of ozone per year since 1978 show significant thinning of this protective shield.

Example of the Breakdown of Stratospheric Ozone by CFCs

Equation 1: $CFCl_3$ + uv radiation → $CFCl_2 + Cl$

Equation 2: $Cl + O_3 \rightarrow ClO + O_2$

Equation 3: $ClO + O \rightarrow Cl + O_2$

In 1–2 years, one Cl atom will repeat Equation 2 about 10,000 times. (Cl = free chlorine; $CFCl_3$ and $CFCl_2$ are two types of CFCs; O_2 = oxygen; O_3 = ozone; ClO = chlorine monoxide)

Atmospheric scientists have concluded that chlorinated compounds—in particular, CFCs—are largely responsible for destruction of the ozone layer. CFCs linger in the atmosphere for many years after they are released. Eventually drifting upward into the stratosphere, they are exposed to radiation from the sun, which breaks the molecule apart, producing free chlorine. The free chlorine molecules can then either combine with O and O_2, preventing the formation of O_3, or combine with O_3 to produce ClO and O_2, breaking up O_3 molecules. Both reactions reduce ozone concentration in the stratosphere.

continues on next page

Chlorine and Ozone—CFCs

continued

International efforts have been made, primarily under the Montreal Protocol of 1987, to phase out the production and consumption of CFCs. By 1996, the production and import of Class I ozone-depleting chemicals (except methyl bromide) were phased out in the United States. Although the ozone layer is expected to recover as a result of efforts to phase out CFC production, this recovery will take some time because of the chemical's persistence in the stratosphere.

Examples of Class 1 Ozone-Depleting Chemicals
- CFCs
- Halons
- Carbontetrachloride
- Methyl chloroform

HEALTH EFFECTS

The reduction of the ozone layer allows an increased amount of ultraviolet light (UV) to reach the earth's surface. Increased exposure to UV light is known to cause skin cancers and to weaken the immune system. Approximately 800,000 cases of skin cancer are reported annually in the United States. Those cancers are more common in individuals with lightly pigmented skin. In 1995, there were more than 34,000 reported cases of melanoma, the most serious skin cancer. This disease has been increasing annually by approximately 4 percent. According to the American Cancer Society, the vast majority of skin cancers diagnosed each year are related to ultraviolet light exposure.

EFFECTS ON TERRESTRIAL PLANTS AND AQUATIC ECOSYSTEMS

Increased ultraviolet B (UVB) radiation can directly and indirectly affect plants. Direct effects include the inhibition of photosynthesis, DNA damage, changes in the plant's morphology, and biomass accumulation. Indirect effects include disruption of the competitive balance in an ecosystem and changes in the timing of life-cycle phases, such as flowering.

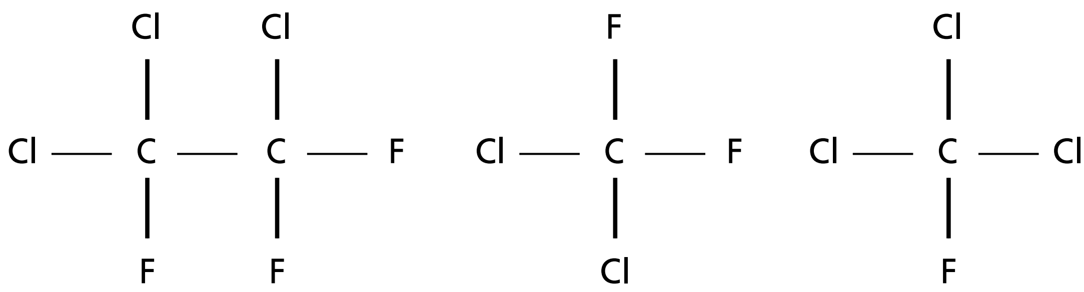
Aquatic ecosystems are also directly and indirectly affected by increases in UVB radiation. It has been speculated that a 16 percent decrease in stratospheric ozone could result in a 5 percent loss of phytoplankton. The loss of phytoplankton is significant because of its crucial position at the base of the aquatic food web. For example, a 5 percent loss could translate into, approximately, a 7-million-ton loss of fish per year. Additionally, solar UVB radiation seems to damage the early developmental stages of fish, shrimp, crab, and amphibians. Indirect effects of ultraviolet light have also been documented. During the summer of 1995, a research team in Saskatchewan, Canada, reported that higher UV exposure resulted in larger populations of algae because the radiation seemed to harm the zooplankton that graze on the algae.

continues on next page

Chlorine and Ozone—CFCs

continued

Structural Formulas for Three Chlorofluorocarbon Compounds



CFC-113 CFC-12 CFC-11

C = carbon F = fluorine Cl = chlorine —— = single bond between atoms

References

American Cancer Society. "American Cancer Society—Cancer Facts and Figures 1998: Selected Cancers." February 6, 1998. <http://www.cancer.org/downloads/STT/F&F98.pdf>, accessed May 3, 2005.

Climate Systems Analysis Group. "Ozone Depletion FAQ Part II: Stratospheric Chlorine and Bromine." 1996. <http://www.faqs.org/faqs/ozone-depletion/stratcl>, accessed May 3, 2005.

Miller, G. Tyler Jr. *Living in the Environment.* Belmont, CA: Wadsworth Publishing Company, 1996.

Nemecek, Sasha. "Holes in Ozone Science: Researchers Look at Loss of the Protective Layer above Our Heads," *Scientific American* 272, no.1 (January 1995):26.

Stratospheric Ozone Hotline, 202-775-6677.

United Nations Environment Programme. "Environmental Effects of Ozone Depletion: Terrestrial Plants." 1996. <http://sedac.ciesin.org/ozone/docs/UNEPsummary96.html#terr>, accessed May 3, 2005.

United Nations Environment Programme. "Environmental Effects of Ozone Depletion: Aquatic Ecosystems." 1996. <http://sedac.ciesin.org/ozone/docs/UNEPsummary96.html#aqua>, accessed May 3, 2005.