Chapter 26

OZONE DEPLETION

Case Study: Epidemic of Skin Cancer

●There has been a dramatic, global rise in the incidence of skin cancers since about 1970 that may be linked to ozone depletion. Other possible causes include an increase in longevity, an association with urbanization, and an increase in leisure time and time spent outdoors in the sun. It is difficult to attribute the increase in cancer rates to a single cause, and probably there are a variety of factors involved, including an increase in UVB radiation. It is believed that a 1% decrease in ozone causes an increase of UVB of about 1-2%. Since 1970, ozone depletion in the atmosphere above the U.S. has been about 10%, which would increase the cancer rates 20-40%. However, the rates have actually increased by 90% of this same period. Clearly the risk of skin cancer depends on the amount of exposure to UVB and the amount of melanin pigment in the skin. Fair skinned people are at greater risk than people with dark skin.

26.1 OZONE

● Ozone (O_3) is a strong oxidant that forms naturally when UVC is absorbed by O_2 in the stratosphere. The O atoms combine with O_2 to from ozone. The peak concentration of about 400 ppb occurs at 30 km near the equator and 15 km at the poles (see Fig. 26.4 and Fig. 26.6). Ozone absorbs much of the UVB radiation (see Fig. 26.2 for definitions of UVA, UVB and UVC). Without this protection, enough UVB would penetrate to ground level to injure of kill most living things. UVA has a longer wavelength, is not absorbed by ozone, and is less dangerous than UVB or UVC. All UVC is absorbed by the atmosphere.

● Ozone concentration is commonly measured in Dobson units (DU), named for the instrument originally used in the 1920s to measure ozone. 1 DU≈1 ppb. Ozone has been monitored for over 30 y now from at least 30 locations. The first signs of ozone depletion came as early as 1957 when the British Antarctic Survey began making measurements. Ozone concentration then was about 300 DU. Then starting in 1970 there was a rapid decline to about 150 DU by 1985.

26.2 OZONE DEPLETION AND CFCs

● Sherwood Rowland and Mario Molina in 1974 were the first to link the production of CFCs to ozone depletion. CFCs where widely used as refrigerants, as propellants in aerosol spray cans, and as solvents (see Table 26.1 and Fig. 26.5). Emissions were on the order of 1.5 million metric tons annually. Their hypothesis was based on the observation that CFCs emitted into the atmosphere are very stable, and with a residence time of about

100 years, CFCs were likely to be mixed into the upper atmosphere where they would be decomposed by UV radiation and would release Cl^- . The Cl^- would then react with and destroy O_3. The Cl^- destroys ozone in a catalytic chain reaction (in which the Cl^- is not consumed by the overall reaction) by the following set of reactions:

$$Cl + O_3 \rightarrow ClO + O_2$$
$$ClO + O \rightarrow Cl + O_2$$

Probably each Cl ion can destroy 100,000 ozone molecules before it is washed out of the atmosphere or before it combines chemically with other molecules such as NO_2 and methane.

26.3 THE ANTARCTIC OZONE HOLE

● First reported in 1985, the ozone layer thins dramatically over the Antarctic during the Antarctic spring (fall here) to form a 'hole' in the ozone layer. A thinning of ozone occurs naturally during the spring due to the effect of polar stratospheric clouds on nitrogen oxide, which facilitates ozone depleting reactions. However, the thinning and size of the hole have been increasing. The size grew from about 10^6 km in the 1970s to about 25 times that today (see Fig. 26.7 and 26.8), and the thinning from 15% to 60%. Although not as severe due to the weakness in the polar vortex, ozone depletion in the Arctic is still alarming. In 1995 Arctic ozone levels were 40% below normal.

26.4 TROPICAL AND MIDLATITUDE OZONE DEPLETION

● While mainly a polar phenomenon, there is also concern about the future of ozone in temperate and tropical latitudes. Depletion of ozone was reported over the continental United States during the cold winter of 1996.

A CLOSER LOOK 26.1: Seasonal Changes in the UV Index: Implications for Ozone Antarctic Depletion

● Fig 26.13 shows seasonal changes in the UV Index at three locations, including Palmer, Antarctica. Palmer shows a higher index in the Antarctic spring, which can be attributed to ozone depletion, higher even than the San Diego which usually has a higher value because of its proximity to the equator.

26.5 THE FUTURE OF OZONE DEPLETION

● Of greatest concern is the longevity of CFCs in the atmosphere and of Cl in the stratosphere. Even if all CFC production were stopped today, the destruction of ozone would continue for years, because there are millions of tons of these chemicals in the atmosphere. About 35% of CFCs now in the atmosphere will still be there in 2100. Moreover, 10-15% of CFC molecules manufactured are still tied up in foam insulation and have not yet been released.

● Ozone depletion could reduce the productivity of the oceans, damage food crops, and will affect human health (skin cancer and cataracts). The National Weather Service now releases a UV index to warn people when protection from the sun is needed. Individuals need to use common sense measures to protect themselves (using sun screen, hats, sunglasses, and protective clothing, and avoiding the sun, tanning beds, etc.).

● A key management issue is whether the ozone thinning is natural or anthropogenic. World production of O_3 increased 7x from 1970 to 1994.

● The Montreal Protocol, signed in 1987 by 27 nations, and later by 119 more, outlined a plan for phasing out CFC production. Most developed nations had ceased production by 1995, and the deadline for developing nations is by the end of 2005. Best estimates are that the destructive chemicals in the atmosphere will return to pre-1980 levels by about 2050. China and India have not signed on to the treaty and a black market for CFCs has developed.

● Several solutions are possible, including recycling of CFC (capture from discarded refrigeration units and reuse for example), and development of substitutes. Two substitutes have been developed. They are hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs). The advantage is that they do not contain chlorine and, although they contain fluorine which reacts qualitatively like chlorine, fluorine is 1,000 time less efficient as chlorine in destroying ozone. Their half-lives are also shorter than CFCs. However, HCFC are 3-5 times more costly than CFCs. Another option is to use propane, which is inexpensive (about 10% of the cost of CFC), but it is explosive and chemical companies see little profit in propane as a substitute.

CRITICAL THINKING

● Why was there such controversy over the role of anthropogenic gases and the ozone hole? The scientific, economic, and political battles surrounding the ozone problem have raged for years. President Regan was not in favor of a ban on CFC production and advised instead that people should wear hats and sunglasses. Table 26.3 contains a number of claims that have been made on both sides of the argument, some of which are contradictory, some false. Have the students evaluate these arguments and identify which statements are hypotheses, inferences, facts (confirmed by experiment), or pseudoscience.

● The UV radiation is 50 times greater at the equator than at the poles. Why? Is this relevant to the debate about the effect of CFCs?

● Scientists reported in 1992 unusually high concentrations of Cl over the N. Hemisphere and warned that this might lead to significant ozone depletion over populated areas, but when this did not occur they were criticized for being alarmist. Was the criticism justified?

Web Resources

http://www.epa.gov/docs/ozone/ A comprehensive EPA site with rules and regulations, enforcement, the Montreal Protocol and a list of ozone depleting chemicals.

http://www.epa.gov/ozone/science/hole/index.html A good EPA site with a link to a good animation of the 2003 Antarctic ozone hole, with links to other good sites.

http://www.cpc.ncep.noaa.gov/products/stratosphere/sbuv2to/ozone_hole.html A NOAA site with graphics showing the history of the ozone hole.

http://jwocky.gsfc.nasa.gov/multi/multi.html A NASA site with superb graphics, quicktime and gif movies, including animations of the N. hemisphere hole. Excellent.

http://www.nas.nasa.gov/About/Education/Ozone/ One more great NASA site with resources.
http://www.antarctica.ac.uk/met/jds/ozone/data/SP0304.GIF A great animation of the 2003/2004 Antarctic ozone hole produced by the British Antarctic Survey.

http://www.antarctica.ac.uk/met/jds/ozone/ A source of great animations produced by the British Antarctic Survey, including a link to the 2003/2004 Antarctic ozone hole.

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