A Reader's Guide to the Ozone Controversy

BOYCE RENSBERGER

The scientific and political debate about the ozone hole and depletion of the earth's ozone layer may seem outside our normal concerns. But many readers, perhaps wary of some of the media coverage of this issue, have asked us for a critical evaluation of the claims. We here publish an award-winning article about the ozone controversy that does attempt to present a balanced scientific picture. In February 1994, this article received the American Association for the Advancement of Science–Westinghouse Science Journalism Award for large newspapers. The author, Boyce Rensberger, is a respected science reporter at the Washington Post, *where the article originally was published on April 15, 1993. Rensberger is a past recipient of CSICOP's Responsibility in Journalism Award. This article generated considerable controversy, and on page 496 Rensberger provides a follow-up especially written for us about the reaction.*—EDITOR

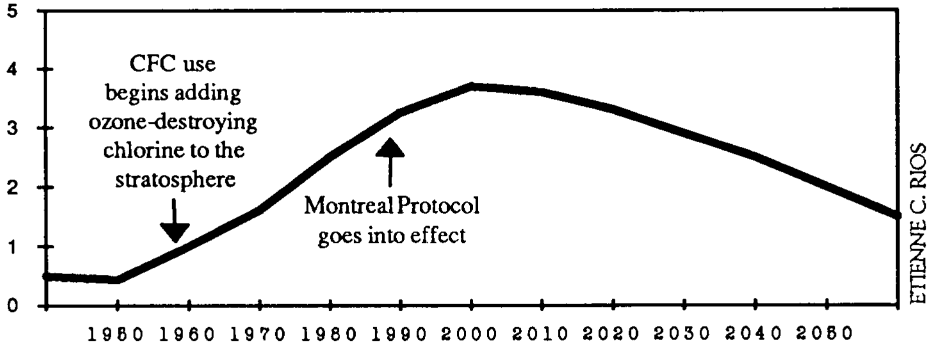
Partly due to actions taken, the threat to the global ozone may be less serious than many dark scenarios have portrayed it. Here's a layperson's guide to the facts about the debate.

After nearly a decade of headlines and hand-wringing about erosion of the earth's protective ozone layer, the problem appears to be well on the way to solution.

As a result of the Montreal Protocol, an international treaty obliging signatory countries to phase out ozone-destroying chemicals, scientists expect the threat of ozone destruction to peak in just seven years. In the year 2000, according to the latest scientific estimates, the ozone layer should start slowly getting thicker and better able to block the sun's harmful ultraviolet (UV) rays.

In fact, researchers say, the problem appears to be heading toward solution before they can find any solid evidence that serious harm was or is being done.

RISE AND FALL OF THE OZONE THREAT
Chlorine in the Stratosphere; Parts per Billion



NOTE: Chart adapted from the *Washington Post* (April 15, 1993); based on latest scientific findings.

This hopeful trend—at variance with the dark scenarios of environmental doom that were pronounced after discovery of the Antarctic ozone hole in the 1980s—is supported not only by growing scientific evidence but even by scientists in the environmental movement.

"The current and projected levels of ozone depletion do not appear to represent a catastrophe," said Michael Oppenheimer, an atmospheric scientist with the Environmental Defense Fund. "But I'm flabbergasted that we let it go this far before taking action. It was a potentially very serious problem."

Richard Stolarski, an atmospheric scientist at NASA's Goddard Space Flight Center, agreed: "I happen not to be of the disaster school. It's a serious concern but we can't show that anything really catastrophic has happened yet, or that anything catastrophic will happen in the future."

Attempts to detect the most feared effect of ozone depletion—increased bombardment of the earth's surface by ultraviolet rays—have failed to turn up any evidence of increased UV influx outside the Antarctic region during the few weeks each year that the ozone hole is open.

If there has been any increase in UV, researchers say, it is too small to measure against a background of normal ultraviolet levels that rise and fall by large amounts for entirely natural reasons on time scales from hours to decades.

Given the expected improvements in the ozone layer, even the ozone hole eventually could stop opening. Already scientists see signs that the hole is not likely to grow much bigger than it has.

Even when the problem reaches its worst in 2000, scientists expect summertime ozone losses over temperate zones to be about 6 percent, double what they are now. Because each percentage point of ozone loss theoretically leads to an increase in UV intensity of 1.3 percentage points, the potential increase in ultraviolet would be about 8 percent.

Scientists calculate that the increased UV exposure a Washingtonian would get in midsummer then will be the equivalent of moving south about 200 miles now. In other words, if you want to know what this area's ultraviolet level will be like in July 2000, go to, say, Raleigh, N.C., this July.

Worst Depletion Occurs in Late Winter

Latitude is crucial because, like time of day and season, it affects the amount of atmosphere that UV must pass through to reach the ground. When the sun is directly overhead, for example, its light penetrates one thickness of atmosphere, but when it is on the horizon, its rays take a slanting path roughly equivalent to 40 thicknesses, and 40 times as much ozone.

This is key to understanding why, even though ozone depletion is worst in late winter (ozone is reduced by 8 to 10 percent), less ultraviolet gets through than in summer, when the ozone loss is milder. Sun angle is so low in winter that the UV passes through more ozone then than during summer when there is less depletion. (Over the tropics, where sun angle is high all year long, there has been no observed ozone depletion.)

"One reason we haven't seen any increase in UV is that we didn't start taking good data long ago," said Stolarski, who nearly 20 years ago was among the first researchers to assert that the ozone layer could be damaged if certain chemicals—expecially chlorine—traveled high enough in the atmosphere.

Ultraviolet Rays Fluctuate Naturally

Because of natural fluctuations in ultraviolent, it is impossible to detect a trend in a short period of data collection.

While there is evidence that the ozone damage is happening, it has proved impossible so far to detect any resulting increase in UV reaching the ground, because ultraviolet fluctuates so much naturally.

"The amount of increase that the theory says we could be getting from ozone depletion is smaller than the error of our best measuring instruments," said John E. Frederick, an atmospheric physicist at the University of Chicago.

"People get all excited about a few-percent change in UV,but it's nothing to get a 20 percent increase naturally," Frederick said. "If an increase of 20 percent were going to be so damaging, there should be no life in Florida," where ultraviolet always exceeded the allegedly dangerous levels once forecast for more northerly latitudes.

Los Angeles Pollution Cuts Levels of UV

Stolarski, Frederick, and other atmospheric scientists say that even if there were good UV measurements going back many years, they still might not show an increase, because other factors, such as increased cloudiness (one of the predicted effects of global warming) and air pollution (including pollution by ozone in the lower atmosphere), might be shielding the ground, compensating for the lost upper-atmosphere ozone.

That, in fact, was a conclusion of one of the most exhaustive studies of the ozone problem ever undertaken, an effort in which nearly 150 scientists from 28 countries collaborated under the auspices of five American, British, and United Nations agencies.

"The decreases in UV-B [the damaging form of UV] caused by increases in [air pollution] since the industrial revolution probably exceed the increases due to ozone depletion," according to the group's latest report, "Scientific Assessment of Ozone Depletion: 1991."

In Los Angeles, Frederick said, there is so much extra ozone in the lower atmosphere in the form of air pollution from cars that it cuts the ultraviolet level on an average day by 6 to 9 percent. On smoggy days, the UV level drops by 20 percent.

Without Shield, Almost Uninhabitable Earth

If any of this comes as a surprise, it may be because most of the mass media coverage of this complex issue has focused on cries of alarm by environmentalists who feared a worst-case scenario in which the planet's protective ozone layer would be thinned enough to let in massive amounts of solar radiation.

If the ozone shield did not exist, the surface of the Earth would be virtually uninhabitable. The amount of ultraviolet that reaches the top of Earth's atmosphere would be lethal to most forms of life if it penetrated to the ground.

The world responded to the environmentalist case. The main threats to the ozone, synthetic chemicals called chlorofuorocarbons (CFCs) used chiefly as refrigerants, solvents, foam-blowing gas, and once as spray-can propellants, are being phased out. In fact, production and sales of CFCs are declining faster than originally projected by negotiators of the Montreal Protocol.

So well are the corrective measures proceeding that scientists who have been looking for effects of ozone depletion say it may not be possible to document any before the massive injection of CFCs into the atmosphere fades away, ending humanity's inadvertent experiment in perturbing Earth's atmosphere.

Nevertheless, debate over various facets of the subject is likely to continue. What follows is a readers' guide to the facts underlying the controversy.

Contrary to Popular Notion, Ozone Is a 'Renewable Resource'

Ultraviolet Radiation Has Created, Destroyed Ozone for Eons

The destruction of ozone—a form of oxygen in three-atom clusters—is nothing new in the atmosphere. It had been happening naturally for billions of years before E. I. du Pont de Nemours and Company Inc. invented CFCs, and for several different reasons. For one thing, ozone is destroyed by the very act of absorbing ultraviolet radiation. And, paradoxically, ozone is created by ultraviolent radiation.

In other words, the ozone layer—contrary to popular impression—is not a limited resource that is being irreparably destroyed. In fact, ozone is made so rapidly in the upper atmosphere that the entire amount destroyed in the annual Antarctic ozone hole (up to 70 percent of what was there) is entirely replaced long before the next hole develops. "Ozone," as Stolarski puts it, "is a renewable resource."

Ozone's life cycle takes place mainly in a slab of atmosphere called the stratosphere, the second layer up from the ground.

The lowest layer, the troposphere, varies in thickness from about six miles at the poles to about 10 miles over the tropics. It contains 80 percent of the mass of air but only about 4 percent of its thickness, figuring that the atmosphere goes up about 250 miles.

The defining characteristic of the troposphere is that the temperature drops as one rises through it in altitude. At the top of the troposphere the air temperature ranges from -60° Fahrenheit over the poles to -120° over the tropics.

(The top of troposphere is highest and coldest over the tropics because the region's fast-rising warm air puffs the atmosphere up. The rising air mass then splits into northbound and southbound air masses, cooling and sinking as they move. This flow transports the ozone made in the tropics to the poles.)

In the stratosphere the temperature profile is reversed. The higher you go, the warmer it gets, until, at its top—about 30 miles above the ground—it can be as toasty as 45° F over the summer pole and a not-quite-balmy -27° over the winter pole.

Ozone is what warms the stratosphere. When an ozone molecule absorbs a dose of ultraviolet light, solar energy turns into heat. While ozone can be found through the entire atmosphere, it is thickest at around 15 miles of altitude, roughly the center of the layer.

Even there, however, it is a rare gas, accounting for just one in every 100,000 molecules in the ozone layer. (Roughly 80,000 are nitrogen and 20,000 are ordinary oxygen.)

Solar Rays Strike Oxygen Molecules

So scarce is ozone that if the 250-mile thickness of the atmosphere were squeezed down so that it was all at the same pressure as at sea level, the atmosphere would be just five miles thick and the ozone would account for just ⅛ inch of it.

Ozone is created (mainly in the stratosphere) when highly energetic solar ultraviolet rays strike molecules of ordinary oxygen (O_2, sometimes called molecular oxygen) and split apart the two oxygen atoms. If a freed atom bumps into another O_2, it joins up, forming O_3, which is ozone.

This new molecule has the special ability to absorb a certain class of ultraviolet rays called ultraviolet-B, or UV-B, which have a wavelength that is especially damaging to living cells. UV-B passes through ordinary oxygen and nitrogen like light through glass.

When ozone absorbs UV-B, it is destroyed, splitting into ordinary oxygen and a free oxygen atom. Usually the loosed oxygen atom links up with another ordinary oxygen molecule to form a new ozone molecule ready to take another dose of UV-B. But if the atom collides with an ozone molecule, it steals one oxygen atom, yielding two molecules of ordinary oxygen.

"The lifetime of an ozone molecule is just a matter of minutes if it's at high altitude," said Bill Mankin, an ozone researcher at the National Center for Atmospheric Research in Boulder, Colorado, "but if it's farther down in the atmosphere, the lifetime can be months."

The difference exists because the low-altitude ozone is shielded from ultraviolet light by the ozone above it. Loss of this shielding effect, for example, after the ozone hole opens over Antarctica, speeds up the destruction and creation of new ozone.

Amount of Ozone in Any Location Varies

In their brief lifetimes, ozone molecules drift and swirl above the Earth's surface, blown in varying concentrations by wind. Atmospheric scientists say that if ozone were visible from space, its changing concentrations would look much like the familiar weather-satellite images of moving clouds.

Because of this constant movement, the amount of ozone above any given spot on the planet—and hence the amount of ultraviolet light filtered out—can vary widely from hour to hour. Ozone concentrations also change more predictably on separate natural cycles of one day, one year, two years, and eleven years.

There are two reasons for such uncertainty—among scientists if not environmentalists—about the relative danger of ozone depletion. One is that all living things have been coping with large swings in the ozone, and hence UV radiation, for millions of years. The other is that because of these natural swings, measurements of ozone levels go up and down in irregular ways and it is hard to see a long-term trend against the background. Scientists refer to it as trying to pick out the signal from the noise.

For example, the annual cycle means that the amount of ozone in the atmosphere above temperate latitudes is naturally about 20 percent higher in April than it is in October. The actual number varies from year to year; 20 percent is an average over the past 60 years.

The natural 20 percent drop in ozone levels is four or five times the 4 to 5 percent drop attributed to human causes—although, of course, in any given moment, the human effect is added to the natural effect.

Amounts of ozone over tropical regions also vary by about 4 to 5 percent over a roughly two-year cycle, in step with a biennial reversal of the prevailing high altitude winds over the equator. In addition, the roughly periodic warming of the southern Pacific Ocean surface known as El Niño also causes tropical ozone levels to fluctuate by 3 to 4 percent. Sometimes El Niño and the biennial reversal are in phase, their effects adding together; at other times they almost cancel out each other.

Even the 11-year sunspot cycle plays a role, the presence of sunspots corresponding to times when the spectrum of solar radiation is most favorable to creating ozone.

"You've got to take the solar cycle into account," said James Angell, who monitors global ozone cycles for the National Oceanic and Atmospheric Administration. "If you don't, you could see an ozone change and think that something else caused it."

Angell's data show that global ozone levels rise and fall about 2 to 3 percent through a normal solar cycle. For example, from 1979 (a maximum in the sunspot cycle) to 1985 (a minimum) global ozone levels dropped because of the solar cycle. This happens to be the period in which the Antarctic ozone hole was first detected.

Since then, the cycle rose again, peaking in a maximum that ran from 1989 through 1991. But during what should have been a period of high ozone production, Angell's observations show ozone declined by 2.7 percent. This suggests other factors, possibly including human causes, pushed depletion faster than creation.

One of the big unknowns, incidentally, is whether the depletion of ozone over temperate latitudes has anything to do with the ozone hole over the South Pole. One theory suggests that destruction of ozone there is slowly draining ozone from all over the world faster than it can be recreated. A rival theory holds that temperate zone ozone is being broken down by a separate phenomenon.

"All the factors that affect ozone go on simultaneously and that makes it very hard to pick out any one of them and say it's responsible for thus and such a part of the change," Stolarski said. "Some things are extremely solidly known and some are not. One thing we can say is that we are very confident the overall depletion of ozone is real."

In the Debate About Ozone No Depletion in Rhetoric

Public debate over the possible effects of an eroding ozone layer often has been characterized by inflammatory claims and doomsday rhetoric.

Vice President Gore's popular book, *Earth in the Balance: Ecology and the Human Spirit*, says ozone depletion has become so bad that hunters in Patagonia are finding rabbits blinded by increased ultraviolet. Anglers, Gore reports, are catching blind fish. Other accounts add that Patagonian sheep are going blind.

The reports gained credibility because Patagonia is at the tip of South America, not far from the Antarctic ozone hole. Yet, efforts to link the rabbit and fish claims to ozone depletion have failed. And the sheep, it turned out later, just had eye infections. While ozone scientists have not made such claims, some have adopted similarly dramatic language. In a booklet called "Report to the Nation: Our Ozone Shield," researchers at the National Oceanic and Atmospheric Administration say, "Life as we know it is possible in part because of the protection afforded by the ozone layer," but that is now "in jeopardy." They called the discovery that industrial chemicals are to blame "a dark message for the world."

Even environmentalists have found some of the debate hard to take. "Unfortunately, we have very little hard data on the effects of ozone depletion," said Michael Oppenheimer of the Environmental Defense Fund. "To begin with, no one knows how much increase in ultraviolet there's been. All we can really say is that there has been a likelihood of some increase in some areas. When there isn't much data, there's room for lots of wild speculation."

One of the most widely repeated claims is that during the past decade skin cancer rates—known to be linked to UV exposure—have doubled. While true, the fact is that skin cancer rates have been climbing steadily through most of this century.

According to data from the American Cancer Society, for example, the skin cancer rate in the United States now is nearly eight times higher than it was 30 years ago. Because there is a long lag between exposure and disease, the 732,000 Americans who are expected to get skin cancer this year will be suffering for their exposure to ultraviolet long before CFCs became a threat.

Decline Found in Planktonic Organisms

The rising trend, cancer researchers say, is the result not of ozone depletion or increased UV (if anything, UV levels have declined in populated areas because of increasing low-altitude air pollution), but of lifestyle changes, such as wearing skimpier clothing in summer, spending more time outdoors, and spending more of that time in southerly altitudes.

Still, it is true in principle that if ultraviolet levels increase, they should raise the number of skin cancer cases—at least among light-skinned people—and assuming the trend toward less tanning and more use of sunscreens does not continue. One rule of thumb scientists use is that for every decline of 1 percentage point in ozone, there is a 1.3 percentage point increase in the amount of DNA-damaging UV.

The only credible claim of a biological effect that has already occurred comes from those who study microscopic creatures in the ocean surrounding Antarctica. Ray Smith of the University of California at Santa Barbara has found evidence of a 6 to 12 percent decline in the number of these planktonic organisms while the ozone hole is open. Some scientists criticize Smith's methods and say the results probably overestimate the damage.

"One problem is that we only began studying this after the ozone hole was in existence," said Deneb Karentz of the University of San Francisco, who also studies Antarctic plankton. "If these were organisms that were extremely sensitive to UV, they could be gone now."

Despite the hole, the planktonic organisms are not helpless. Karentz has discovered that virtually all of them can protect themselves against increased ultraviolet with a natural sunscreen, a colorless molecule that absorbs UV-B. Algae make the sunscreen in response to an increase in UV. Planktonic animals extract it from the algae they eat and, instead of digesting the molecules, distribute them in their own bodies.

So effective is the molecule, Karentz said, that an Australian firm is working to synthesize the substance and sell it as a natural sunscreen for humans.

Testing for Effects of Higher UV Levels

Botanists have found that land plants also make their own natural sunscreens, molecules called flavenoids. These molecules are analogous to the melanin that human skin makes to tan itself for protection from ultraviolet, except that plants can do it much faster. Some plants respond within hours to changes in UV level, increasing their flavenoid content each morning as the sun moves higher, lowering it if the day turns cloudy to take in more of the visible wavelengths needed for photosynthesis, and dropping it to low levels through the night.

Flavenoid content also varies with latitude. The farther south a species' growing range, the higher the flavenoid content. But each species has a limit. If it is transplanted still farther south, the plant may not be able to make enough flavenoid to protect itself and its growth will be retarded.

While scientists find no solid evidence that land plants are suffering from increased ultraviolet bombardment, experiments are under way to see what might happen in the future if UV levels go up significantly.

Alan Teramura of the University of Maryland, for example, has been growing various food crops and tree species under sunlamps that boost the UV levels by as much as 50 percent. This is several times as much extra ultraviolet as is expected in the year 2000, when ozone depletion is projected to reach its worst.

At these high doses, about two-thirds of the 50 varieties tested displayed reduced yields. The most sensitive soybean varieties, for example, lost as much as 25 percent of their yield. Other varieties were unchanged and a few increased their yields slightly. Because soybeans are Maryland's leading field crop, researchers are working to develop varieties with enhanced UV-B resistance.

The effect on perennial species, such as loblolly pines, was more insidious. Teramura has found that with each passing year the trees' growth was stunted by a larger amount. Studies are continuing to see whether the effect of massive UV doses will eventually kill the trees.

"The effects in trees that we see now may be small and subtle but they accumulate over time," Teramura said.

Still, "I'm optimistic," said the Environmental Defense Fund's Oppenheimer. "I believe the Montreal Protocol is already solving the problem before it gets out of control." □

Hard Time Dealing with Good News: Reaction to My Ozone Story

BOYCE RENSBERGER

The reaction to my ozone story was swift. Some readers were perplexed because they were under the impression that the amount of ozone depletion was approaching alarming proportions. My story didn't square with the prevailing public image of the problem. Other readers were angry because they were sure the world was already plunging into ultraviolet hell. They thought I was maliciously trying to discredit the environmentalist movement. There were letters, phone calls, and clippings of articles in environmentalist advocacy publications branding me an enemy of the planet.

One of my favorite phone calls came from a man who sputtered with anger and accused me of not caring that because of the ozone hole polar bears were going blind. I tried to explain that the hole is at the South Pole and the bears are closer to the North Pole, but he regarded that as an obfuscatory tactic.

On a more rational level, the first perplexed group I heard from was the Congressional environment caucus, which is a group of legislators and staffers who deal with such issues. A member phoned me to say that the caucus was so startled by my story that they had summoned a prominent atmospheric scientist at NASA to come in and please tell them what gives. According to my informant, the caucus members were pretty sure my story was way off base. "You ought to come and see what happens," he said. "I think you'll find it interesting."

I went, sat in the back of the room, and nobody recognized me. Well, the NASA scientist said (and I paraphrase): Rensberger's story is basically correct on the facts, but there is a problem with his tone.

I was to hear the "tone" complaint many times. It puzzled me that a story could be factually correct and written in what I thought was a straight, unemotional style but be considered