

# **OZONE ALERTS**



***Here at Ground Level, Too Much Ozone Gas Accumulates--  
but in the Stratosphere, the Ozone Layer has Holes...***



The National Institute of Environmental Health Sciences  
National Institutes of Health

***...Like Sunglasses with  
a Badly Cracked Lens.***



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## KINGSLEY — A TOUGH COOKIE CRUMBLES

Kingsley is 24 and in training for competitive bicycle racing. She is one of 50 volunteers in a controlled study of ozone. Right now, she is pedaling hard on a stationary bike in a chamber where ozone can be added in varying amounts to clean, filtered air.

The level in the chamber is 320 parts of ozone per billion parts of clean air. That is four times the federal air quality standard of 80 ppb currently set by the Environmental Protection Agency—but levels of

320 do occur in major cities. In Los Angeles, for example, ozone levels have climbed to 360 ppb and in some large cities in other countries, that still happens.



Although Kingsley is used to biking 20 miles a day and running seven miles three times a week, now, after 47 minutes, she's hurting.

Seven minutes later, at 54 minutes, her chest is sore and tight, she is wheezing, and she feels nauseated and "close to fainting."

She has to quit.

Dismounting, she flops onto the floor. After ten minutes, she recovers enough to get up and be tested.

The tests show Kingsley's lung function—the amount of air she can expel after taking a deep breath—has decreased more than 30 percent.

Even 24 hours later, she still feels bad. When checked by telephone, she complains that most of her symptoms have persisted.

Kingsley's sensitivity to ozone is extreme. However, studies like these show that, at some point, ozone exposures above the norm can affect respiratory functioning in all of us.

## OZONE IS UNSTABLE and IRRITATING: AS WHEN A THIRD PERSON BREAKS IN TO DANCE WITH A HAPPY PAIR

Ozone is a special form of oxygen. Like ordinary oxygen, ozone is one of the many gases in the air we breathe. Like oxygen, ozone is made up of oxygen molecules. But, while the molecules of ordinary oxygen are made up of two chemically linked oxygen atoms, the molecules of ozone are made of three such atoms. With its third atom of oxygen, ozone is not very stable—that is, it ordinarily doesn't last very long.

A little ozone occurs naturally. An energy source such as lightning can produce it—**temporarily breaking up pairs of oxygen atoms and reforming them as chemically linked clusters of three oxygen atoms: ozone.** People, other animals and plants tolerate such naturally occurring, short-lived ozone pretty well. But when ozone builds up—generally as a result of our use of fossil fuels—it reacts very strongly with animal and plant tissues, and even damages tough materials such as rubber, plastics and outdoor paints.

You've probably seen hydrogen peroxide fizz—and perhaps felt it burn your gums or skin tissues, or “smart.” Like ozone, hydrogen peroxide is closely related to a very stable molecule: water, or  $H_2O$ . With an added oxygen atom, it changes to  $H_2O_2$ , becoming very reactive.

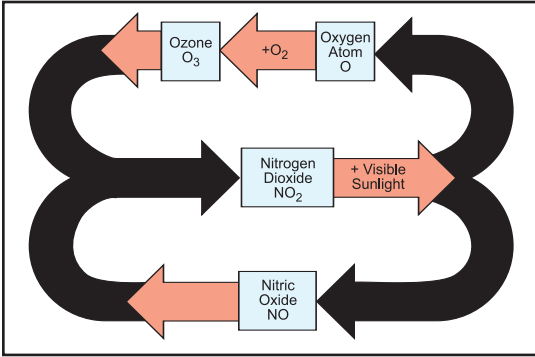


The fizz and burn of hydrogen peroxide on a scratch or wound illustrate how, at high concentrations, ozone's own strong reactivity can irritate and damage the sensitive tissues of your eyes, lungs, nose, sinuses and throat, causing burning eyes, shortness of breath, chest tightness, wheezing, coughing and nausea.

The sustained, higher levels of ozone that cause these effects usually begin with human activity.

That is, when we use electricity for our lights, computer and TV, when we heat our houses and run our cars and SUVs, or even when we roast chestnuts on an open fire or charcoal a steak, these activities often require the burning of fossil fuels—hydrocarbons such as

gasoline, heating oil, firewood, charcoal and the coal for power plants. This combustion releases oxides of nitrogen, which are gaseous combinations of oxygen and nitrogen, nitrogen being another common gas in our atmosphere. One of these combinations is nitrogen dioxide ( $\text{NO}_2$ ). When  $\text{NO}_2$  absorbs energy from sunlight, it breaks down to nitric oxide ( $\text{NO}$ ) and a free oxygen atom.



The free oxygen atom then barges into the oxygen pair to form the linked triplet of ozone ( $\text{O}_3$ ).

### WHEN OZONE ACCUMULATES, IT HURTS PEOPLE, PETS, CROPS

Normally, ozone converts back to oxygen. However, airborne hydrocarbons

(from motor vehicles, industrial emissions and other kinds of incomplete combustion and solvent use) can disrupt this conversion, allowing the ozone to accumulate. Because sunlight and heat play roles in the smog process, ozone concentrations most often rise in the warmer months of the year and peak in the warmer hours of the day.

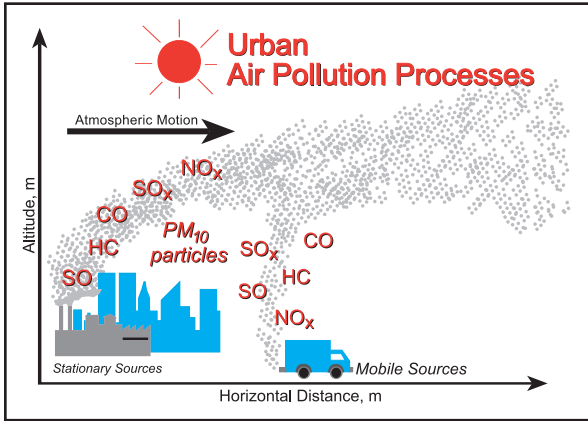
While winds might dissipate the ozone, temperature inversions frequently occurring during warm weather over many cities can hold down and stagnate the lower atmosphere, allowing ozone to build up. And there you have it: grey, thick, photochemical smog—urban smog.

*AN INVERSION — You hear about it on TV weather a lot: Normally, warm air rises until it cools at lower altitudes, thus moving and mixing the air. A temperature inversion occurs when the upper air is warmer and prevents the lower air from rising, trapping it in place.*

Thus, the centers of ozone pollution are the great centers and suburbs of humankind's activity: Los Angeles, Houston, Atlanta, New York, Boston and other large metropolitan areas. (That's why in some cities in developing countries, people are somewhat proud of smog—as a sign of industrialization's progress.)

In rural areas, less ozone is likely to accumulate. There are fewer

gasoline automobiles, homes and factories. In addition, moisture in rural soil and trees absorbs some of the radiant energy from the sun, keeping these areas cooler than nearby cities. But rural areas do not



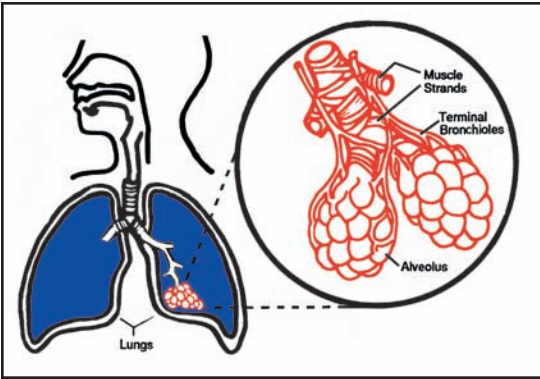
escape the effects of ozone entirely. Trees themselves generate some hydrocarbons and add to ozone levels. Many power plants that burn fossil fuels are in rural areas, increasing the concentrations of oxides of nitrogen in rural air. According to “the weatherman,” the National Oceanic and Atmospheric

Administration, rural sections of the East and South have among the highest summer ozone readings in North America partly as a result of spillover from cities and suburbs.

A study of hikers on the White Mountain in New Hampshire in the NIEHS journal *Environmental Health Perspectives* for February 1998 showed lung function rose and fell with ozone levels, even though they remained within the range common in urban parts of the United States.

Crops suffer as well, with up to \$3 billion in agricultural losses a year in the United States. The forests that we harvest for paper and building materials are also susceptible to ozone-induced damage. In China, heavy regional haze may cut food production 10-30 percent, according to one estimate, contributing to food scarcities and hunger.

**HOW OZONE DISTURBS YOUR BODY** — Inhaled ozone travels down the windpipe and enters the lungs through the large bronchial tubes, which branch into smaller airways, or bronchioles. At the end of the bronchioles are tiny air sacs called alveoli, which fill up and expand like little balloons to put oxygen into the bloodstream. Ozone primarily injures these key oxygen exchangers, the alveoli, along with the bronchioles.



Animals also suffer from ozone. Studies demonstrate how ozone exposure injures their lung cells and causes unusual changes in lung tissue. Other studies have shown that ozone can make people more susceptible to bacterial pneumonia, a potential killer.

People with existing lung diseases—asthma, bronchitis, or emphysema—are particularly vulnerable to the respiratory effects of ozone.

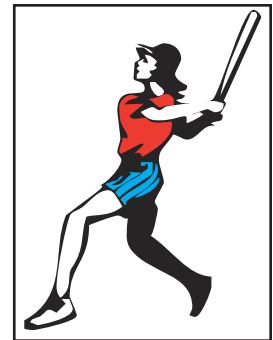
There are also particularly sensitive individuals.

### TESTS SHOW LOST LUNG CAPACITY, POORER ATHLETIC PERFORMANCE

A third group that may be particularly susceptible to ozone is made up—ironically—of healthy, not-particularly-sensitive people who exercise a lot outdoors. Studies show that adults exercising vigorously react more to ozone exposure than do adults at rest. People working or exercising increase their breathing rate, so that they inhale more ozone and thus a higher dose reaches the target tissues of the bronchioles and alveoli.

Other tests have shown:

- Ozone affects a person's vital lung capacity—the volume of air that can be expelled from fully inflated lungs. In controlled tests, a 5 to 10 percent reduction occurred in volunteers engaged in moderate exercise for 6.5 hours at just 80 ppb. In the “real world,” active kids at camp showed reduced vital lung function when ozone was higher than normal.
- Athletic ability, as measured by performance on stationary bikes or treadmills, has been shown to be poorer at 180 ppb than among controls performing in normal air.





- Ozone concentrations can make the small bands of muscles that help control breathing more sensitive to dry air, cold or dust, so they contract, narrowing the airways and making breathing more difficult.
- In five cities studied by researchers in Massachusetts, hospital admissions for pneumonia and flu were highest in the cities with higher maximum ozone levels and particulate levels.

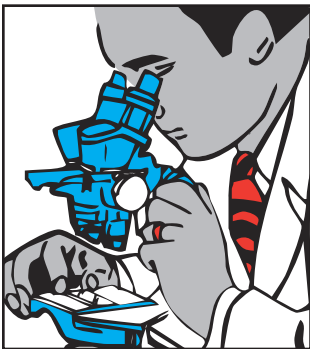
**A GENE FOR OZONE SENSITIVITY, MAYBE A TREATMENT — AND STUDIES THAT DON'T FIND OZONE TO BE CARCINOGENIC**

In studies funded by the National Institute of Environmental Health Sciences:

- At the Johns Hopkins University in Baltimore, researchers have identified a gene that may play a role in ozone sensitivity, and
- Scientists at Rutgers University in New Jersey have found they can prevent some ozone-related lung damage by pretreating cells with an amino acid called taurine that may develop into a treatment for patients.



Other NIEHS-supported studies include the Harvard University Six-Cities Study—expanded to include 24 locations—which has generated one of the largest known databases on the health effects of outdoor and indoor air pollutants.



Because ozone is so reactive, so irritating, you might wonder if it causes cancer. There's some generally good news on that score: The National Toxicology Program, headquartered at NIEHS, found that rats exposed to ozone for from two years to 30 months did not have a significant increase in tumors—nor did ozone add to the risk of rats exposed to a known carcinogen in tobacco smoke. Only at the high exposure of 1 part per million did a marginal increase in lung tumors appear, and that could be coincidental.



## OZONE HAS PROVED HARD TO REDUCE

Some emissions have been greatly reduced under the Clean Air Act of 1970 (with amendments in 1977 and 1990). Today's air is noticeably cleaner than a few decades ago. But ozone, which results from a reaction between emissions and other substances, has proved harder to reduce. A report of the National Academy of Sciences a few years ago put it pretty bluntly: State and federal restrictions, along with industry practices, had "largely failed" to decrease ozone exposures. As the century ended there were still 32 "nonattainment" areas containing 40 cities in which people are exposed to ozone in excess of the air-quality standards set to protect people's health. A nonattainment area may involve three urban, highly populated states, such as New York, New Jersey and Connecticut, so many people are exposed to unacceptably high levels of ozone.

As for ozone in the stratosphere, turn the page...

## IN THE STRATOSPHERE, THE NEWS IS BAD, BUT PROBABLY WOULD BE WORSE EXCEPT FOR AN ECCENTRIC DUTCHMAN AND TWO AMERICANS ON A MISSION

Even small changes in the ozone layer in the stratosphere have been linked to an increase in skin cancer. Further deterioration could be even more harmful. Indeed, without the ozone layer's filter, life on earth as we know it could not exist.

*In the 1980s, an ozone hole was found to be forming every spring over Antarctica, where cold, stratospheric temperatures promote the chemical reactions that destroy ozone. Scientists are watching for UV damage to penguins, whales and the vital food chain of fish and other sea creatures, including the microscopic algae (phytoplankton) that are the base food for the undersea food chain.*

The Arctic has no land mass and is warmer than Antarctica, but an ozone hole now appears over the North Pole as well. However, prospects for life on earth are brighter today than they undoubtedly would have been if there had been no Paul Crutzen, a Dutchman who taught himself chemistry. He dresses eccentrically, showing up for a formal-dress lecture in sandals and open shirt and talking from scribbled notes—yet, reported the New York Times, “mesmerizing” his audience. In 1970, Dr. Crutzen showed that the ozone layer is created naturally by the action of sunlight on oxygen—and can be destroyed by compounds called chlorofluorocarbons (CFCs).



This helped lead Mexico-born Mario Molina and F. Sherwood Rowland, both U.S. citizens working at the University of California at Irvine, to discover soon afterward

that chlorofluorocarbon gasses from earthly air conditioners and spray cans could waft intact to the stratosphere, where they might persist a hundred years, gradually being broken down by the sun's UV rays into free chlorine atoms.

Drs. Molina and Rowland showed that each chlorine atom could then destroy thousands of ozone molecules in a long chain reaction.

Much of the world, but perhaps not quite enough of it, was shaken by the 1974 prediction by Molina and Rowland that if humans continued to make and emit CFCs, the ozone layer would be weakened.

To the consternation of the industries making and using CFCs, the two scientists became salesmen on behalf of ozone protection. Gradually, confirmatory data accumulated and, 11 years later, in 1985, an actual hole in the ozone layer was reported by an English scientist.

That wake-up call was acted upon quickly, as political actions go, in the 1987 Montreal Protocol, which called for the international phasing out of CFC-containing products, as well as in the U.S. Clean Air Act Amendments of 1990. These were major steps toward protecting the ozone shield from further damage by eliminating use of these ozone-depleting chemicals.



In awarding the Nobel Prize in Chemistry to Molina, Rowland and Crutzen in 1995, the Royal Swedish Academy of Sciences said they had contributed to the world's "salvation from a global environmental problem that could have catastrophic consequences."

But phasing out the use of ozone-depleting chemicals has been no quick fix. It may slow the destruction of the ozone layer and eventually halt it, perhaps

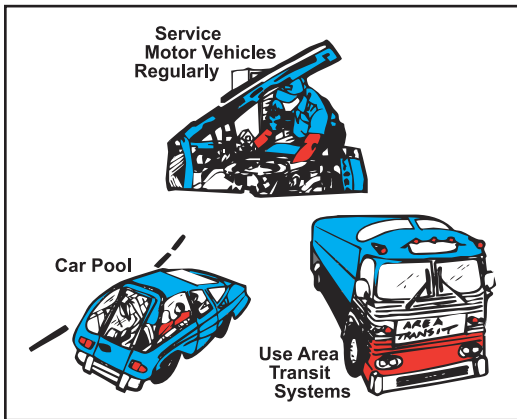
allowing it to rebuild. But a NASA satellite showed the hole in the shield over the Antarctica (South Pole) reached 10.5 million square miles on September 19, 1998—bigger than ever.

No one can predict the future with certainty, but over the 21st Century, the shield may slowly recover.

## AFTER THAT GLORIOUS CHEMISTRY, WHAT'S LEFT TO SAY, BUT: WHAT CAN I DO?

In terms of ozone concentrations in the lower atmosphere, you can:

- **Run Early or Late.** Protect yourself in warm weather, when ozone concentrates, by exercising in non-congested areas, in the mornings, before ozone levels rise with daily temperatures, or in the evenings, after they've declined.
- **Keep Car Tuned, Tires Inflated.** Protect your environment by keeping your car in tune and your tires inflated to the recommended pressure, and by using your car sparingly, finding alternatives.



- **Cap Chemicals.** Keep household cleaners, solvents and other home and garden chemicals tightly sealed, to reduce the evaporation of volatile organic compounds which contribute to the hydrocarbon content of the atmosphere.

- **Limit Burning.** Whether your locality permits it or not, avoid burning trash and building inefficient fires, such

as smoky grills and fireplaces—especially if your area is experiencing alerts.

- **Conserve Power.** Join in your electric utility's conservation programs, such as periodic air conditioning cut-backs that also reduce your bills. Support local ordinances and regulations related to conservation and to burning and smoke restrictions, so that you and your neighbors can breathe easier.

In terms of the stratosphere, you can:

- **Repair Leaky AC.** Make sure that old-style refrigerants used in your auto are not released into the atmosphere but are recovered in a government-approved program, as required by law. Repair leaky units before refilling them.
- **Dispose of Fridge or AC Carefully.** Check with your local authorities about the proper disposal of old refrigerators and air conditioners.
- **Protect Skin.** Prevent sunburn and reduce your risk of skin cancer, malignant melanomas and cataracts by protecting yourself with a wide-brim hat, tight-weave clothing, sunglasses and a sunscreen of SPF 15 to 30.

The story of ozone illustrates what we at the National Institute of Environmental Health Sciences say: **YOUR ENVIRONMENT IS YOUR HEALTH.**

Likewise, the research on ozone—like previous research NIEHS has carried out and supported on asbestos and lead and industrial chemicals, and on the water we drink—illustrates that good environmental health research is the basis for intelligent action—and for preventive health measures that can save health, lives and dollars.



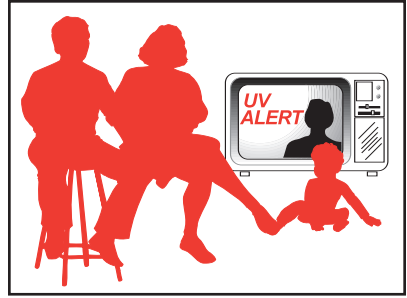
## GROUND LEVEL AIR QUALITY ALERTS —

Too much ozone at ground level can make your eyes smart, can reduce your lung capacity and, in extreme cases, can make it hard to breathe. Too much ozone at ground level can make even a very fit person, an athlete-in-training, pretty sick.

Local broadcast and newspaper air quality alerts generally correspond to federal ozone standards:

Ozone Index Value	Precaution
0-50 (good-GREEN)	Best for outdoor activity.
50-100 (moderate-YELLOW)	Unusually sensitive people should consider limiting prolonged outdoor exertion.
101-150 (unhealthy-ORANGE)	Active children and adults, and people with respiratory disease such as asthma, should limit prolonged outdoor exertion.
151-200 (unhealthy-RED)	Exercise early/late; indoors when possible. Everyone, especially children, should avoid (if sensitive) or limit prolonged outdoor exertion.
Above 200 (very unhealthy--PURPLE)	Active children and adults, and people with respiratory disease such as asthma should avoid all outdoor exertion. Everyone else should limit outdoor exertion.

Note: When ozone begins to rise, fires, outdoor grilling and individual auto use should be restricted.



## ULTRAVIOLET (UV) ALERTS —

To help avoid painful sunburn and blisters and such long-term problems as skin cancer and sight-dulling cataracts, many weather reports now include information on the UV Index.

Using two National Oceanic and Atmospheric Administration-operated satellites, the National Weather Service and the Environmental Protection Agency forecast the UV risk (or Index Value) based in part on the wavelengths of the UV radiation (some being more harmful than others) and on whether clear skies or cloudy are expected. They then suggest preventive actions:

<b>UV Index Value</b>	<b>Precaution</b>
0-2 (minimal)	Wear hat or cap.
3-4 (low)	Hat and sunscreen of SPF 15 or more.
5-6 (moderate)	Hat, sunscreen of 15+, stay in shady areas.
7-9 (high)	As above, plus stay indoors 10 a.m. to 4 p.m. if possible.
10+ (very high)	Stay indoors as much as possible, especially between 10 a.m. and 4 p.m., and if you go outside, take all other precautions, as above.

To reduce the risk of cataracts and other eye damage, sunglasses are advised for UV values of 5 (moderate) or higher. Good sunglasses are also advised at the beach, on the water or on snow, at all times, even when the index is minimal.



## SAVE YOUR MONEY — RESIST OZONE ‘AIR FRESHENERS’

Having just read a bit about ozone, you might think it darn odd that someone might want to breathe more of it—or want you to. But, despite Federal Trade Commission and state actions against their claims, there remain people who want to take some money from you in exchange for an “air cleaner” or “air freshener” that claims to work by generating ozone.

You can read a long report at <http://www.epa.gov/iaq/pubs/ozonegen.html> on why this is a silly and potentially harmful idea. The bottom line is this: To generate enough ozone to be potentially effective, the ozone equipment would have to produce dangerous amounts of ozone. Contrary to suggestions from some sales people, no federal agency approves, much less recommends, ozone generators for use in occupied spaces.

There are other kinds of air cleaners you can buy. Some use high efficiency particle arrestance (HEPA) filters or charcoal to work safely, according to a California consumer bulletin in 1998. But as for the cleaners using ozone: The bulletin states that air cleaners that rely on ozone generation just don’t destroy enough microbes, remove enough odor sources or reduce indoor pollutants enough to provide health benefits—and “may contribute to eye and nose irritation or other respiratory health problems” and “can cause damage to building materials and electronic devices.”

## SO YOU WANT TO BE OZONE-HEALTHY? - A QUIZ

1. Ozone at ground level reduces your (a) waist, (b) lung capacity and athletic performance, (c) IQ, (d) all of the above.
2. Ozone is made up of how many atoms of oxygen? (a) three, as in  $O_3$ , (b) two, as in  $O_2$ , (c) three, as in  $H_2O$ , (d) four, as in  $O_4$ ?
3. When ground-level ozone is high, you get smog and sometimes (a) burning eyes, (b) shortness of breath, (c) irritation of the nose and throat, (d) all of the above.
4. Sustained, high levels of ground-level ozone result from human activities such as (a) burning fuels, (b) spilling gasoline, (c) roasting chestnuts and steaks on an open fire, (d) all of the above.
5. Combustion produces, among other oxides of nitrogen, nitrogen dioxide ( $NO_2$ ). One of the oxygen atoms is freed to form the linked triplet of ozone,  $O_3$  when (a)  $NO_2$  absorbs energy from sunlight, (b)  $NO_2$  tires, (c)  $NO_2$  is inhaled, (d) all of the above.
6. Without a protective ozone layer in the stratosphere, life as we know it could not exist. But in the 1980s, (a) an ozone hole appeared over the U.S., (b) too much ozone accumulated and the sun was dimmed, (c) an ozone hole was found to be forming every spring over the South Pole, (d) ozone-polluted plankton was shown to be making penguins sick.
7. Chlorofluorocarbon gasses were shown to waft up to the stratosphere, from earthly uses in air conditioners and spray cans, and be broken down by the sun's ultraviolet rays into ozone-destroying (a) hair gel, (b) coolants, (c) free chlorine atoms, (d) calcium-bound fluorosis.
8. Because of political action to reduce chlorofluorocarbons, the ozone shield (a) has been reformed, (b) may be fine by 2010, (c) may recover over the 21st Century, (d) can't get better.
9. To reduce ground-level ozone, we can (a) wear sunscreen with an SPF of 15 or more, (b) stay indoors in mid-day, (c) avoid genetically modified foods, drugs and cosmetics, (d) cap chemicals, limit burning and conserve power.
10. In terms of the stratosphere, you can (a) keep tires low, (b) burn trash only in the morning, (c) properly dispose of old refrigerators, air conditioners and their coolants, as required by law, (d) watch for air quality alerts.

(Answers on following page.)

**Answers:**

1b, 2a, 3d, 4d, but roasting chestnuts and grilling steaks at least smell awfully good; 5a, 6c, and then, later, a North Pole, or Arctic, hole appeared; 7c, fluorosis being a darkening of your teeth from excess fluorides; 8c, at least that's the hope; 9d, though it is good to wear sunscreen for protection against the sun's UV rays because of the damaged ozone shield; 10c, you should also watch for air quality alerts, but these apply to ground-level ozone.

If you got less than eight right, don't bother applying to the major TV quiz shows. If you got less than six, you should have read the booklet first.

**The National Institute of Environmental Health Sciences**  
National Institutes of Health  
U.S. Department of Health and Human Services

**For additional information on the work of NIEHS,  
and the National Toxicology Program, go to *http://www.niehs.nih.gov*  
or write NIEHS Communications-Public Liaison,  
Box 12233, Research Triangle Park, NC 27709**

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