UV and Me

by Kris Korfanta and Annie Bergman
Modified from "Ozone, UV and You," Global Change Education Resource

Overview
Students design an experiment to explore and demonstrate the effects of ultraviolet rays on inanimate objects that react to UV light. They discuss the effects of ultraviolet light on humans, other animals and plants. They discuss the importance of the ozone layer in the stratosphere relative to UV light. Finally, they report on actions they can take to protect themselves from ultraviolet rays.

Objectives
Students will

- Be able to describe the visible and invisible spectrum of sunlight
- Be able to describe harmful effects of ultraviolet light (UV) on humans, other animals, and plants and their protective adaptations
- Understand the atmosphere's ability to shield earth from harmful UV
- Recommend actions to protect themselves from UV

Goals and Concepts

A 2, 27; **B** 3, 5; **C** 1, 2, 5, 13; **D** 5, 7, 8, 10, 13, **E** 8; **F** 6, 14

Grade Levels:
6-9
Time Needed:
Two 45 minute class periods, at least 2 hours apart on sunny days.
Subjects to Integrate:
Science (Chemistry, Biology, Environmental Science, Physiology), Health, Language Arts

Related WWW activity: "Ozone Tag" from the Earth Elements Section
Topics:
Effects of UV rays on health, ozone layer, Wellness

Skills:
Observation, research, writing, social

Materials
Clear ziploc-type bags
sunscreens and sunblocks of varying SPF
inexpensive UV beads
colored papers
timers or access to clock or watch

optional:
UV-protective sunglasses
non-UV-protective sunglasses

Background

Ultraviolet (UV) radiation comprises wavelengths in the sun's spectrum that are invisible to the human eye. There are three types of UV radiation: UVA, UVB and UVC.

UVC: 290-100 nm
The short wavelength UVC could be highly dangerous to plants and animals, but is completely absorbed by stratospheric ozone and does not reach the earth's surface.

UVB: 320-290 nm
Ozone absorbs the shorter UVB wavelengths but allows the longer wavelengths (nearer to 320 nm) to reach the earth's surface, where they can be particularly harmful to plants and animals. UVB can affect humans by causing reddening of the skin (erythema), reducing short-term vitamin-D synthesis, skin cancer, cataracts and long-term suppression of the immune system.

UVA: 400-320 nm
Very little UVA radiation is absorbed by ozone as it passes through the stratosphere. UVA is needed by humans and other animals for synthesizing vitamin D, but overexposure to UVA is thought to promote skin cancer, cataract formation and premature aging.

Why should we care about UV radiation?

- Ultraviolet radiation is a proven human carcinogen.
- Skin cancer is the most common form of cancer in the United States.
- More than 1 million cases of non-melanoma skin cancer are diagnosed yearly in the United States. Most are considered to be sun-related.
- In 2006, over 53,000 cases of melanoma (the most serious form of skin cancer) were diagnosed in the United States. According to the National Cancer Institute's SEER database, an estimated 2,390 men and women were diagnosed with cancers of the eye and orbit in 2008.

We are fed a stream of advice to protect ourselves from UV radiation in all seasons. Yet, we are also surrounded by images of healthy, tanned athletes and models, and advertisements promoting tanning beds and products that will give you a 'healthy' looking tan. We know that spending time outdoors benefits our mental and physical wellbeing, so we need to think of the best ways we can protect ourselves from UV radiation.

Suncreens

- Sunscreens filter UV rays and are rated by their Sun Protection Factor (SPF) in the United States. Health experts recommend using sunscreens with SPF 15 or higher, and reapplying it every 2 hours.
- SPF requirements in the United States only address protection from UVB radiation.
- Sunscreens contain chemicals that are absorbed through the skin and, recent research has indicated that some of these chemicals may act as hormone disruptors.

Sunblocks

- Sunblocks have mineral ingredients that block UVA and UVB rays by reflection, absorption or scattering. An undesirable effect is that they work by leaving an opaque protective barrier on the skin.
- A recent trend is clothing treated with chemical sunblock to give them an Ultraviolet Protection Factor (UPF) rating. A shirt with UPF rating of 50 will block 1/50 (2%) of the UV rays.

The guidelines for measuring SPF can be misleading. For example, following the guideline, a person with fair skin can expect to tolerate 10 minutes of direct sun exposure before burning. The same person wearing a sunscreen with SPF 20 can expect to tolerate 20 x 10 = 200 minutes of sun exposure before burning. This can be dangerous misinformation, as the effect of UV radiation on an individual can vary with altitude, latitude, time of day, season, and type of surface, e.g., water versus land. Think about how well you would fare spending over 3 hours in the sun with SPF 20 applied once. Your tolerance would vary greatly depending on the time of day, if you were skiing, swimming, sweating, or hiking at high exposed altitudes.

Ultraviolet light packs more energy than visible light and causes chemical effects such as bleaching color from paper and destroying the structure of plastics. UV-B can have detrimental effects on our crop production by affecting the physiology and increasing the fragility of crop plants like rice, oats, sorghum, soybeans, and beans.

The effects of UV radiation may be relatively small on overall biomass, but not when the abundance, distribution and effects on individual species are considered. Dissolved organic matter in freshwater and seawater filters some UV, but organisms also redistribute themselves at different depths to avoid UV, changing the community dynamics. Though global decline of amphibian populations appears to be related to several complex, interacting causes, dozens of amphibian species are affected by UV-B. Studies on fish eggs and larvae, zooplankton, phytoplankton, and corals, have implicated UV radiation as part of the cause of their decline.

Ozone (O_3) is formed in the stratosphere when stratospheric oxygen (O_2) molecules are photochemically changed (see how UV radiation is tied to climate change in the "Ozone Tag" activity). Ninety percent of our ozone is in the stratosphere,

15 to 50 miles above the earth. Before photosynthesizing plants evolved in earth's history, the atmosphere did not have a large component of oxygen. About 600 million years ago, the oxygen concentration produced by marine photosynthesizers, reached about ten percent of what it is today and the ozone shield began to form. Before the ozone shield, life existed only in the oceans, protected from ultraviolet rays by water. This ozone layer and the stratosphere protects us from much of the sun's UVA and UVB radiation and all of the UVC.

An estimated 10% reduction in the ozone layer will result in a 25% increase in non-melanoma skin cancer rates for temperate latitudes by the year 2050.

Procedure

In this activity, students will work in teams to test the effects of different sunscreen products and sunglasses on UV-activated beads and paper bleaching.

1. Teams discuss their hypotheses and experimental design. What do they want to test? How will they design their experiment to collect the desired data? They should test UV effects on UV beads AND colored paper (these can be run in separate class periods).
2. Teams are given materials and time to set up experiment.

Protocol suggestions:

UV beads and colored paper must be kept out of sunlight until testing starts.

With markers, label areas that each sunscreen or sunblock will be applied.

Remind students to include a control.

Tests should be timed. UV beads will react quickly to sunlight but students may want to leave colored papers in sunlight for 2 hours.

2. Student discuss their results within teams and share/compare results with other teams.

3. Ask students what practical application they might make from this experiment.

4. Give students copies of Student Activity/Reading Pages 1 and 2 and allow time for all to read the information. Discuss implications of UV rays on human health. Encourage students to take the information home to their families.

5. What are some harmful effects on other life? Some crop species have decreased growth with an increase of UV light. Productivity of phytoplankton, the foundation of marine food chains, decreases with increased UV exposure. Some species of bacteria and viruses become more active when exposed to UV, while some become inhibited. Barbers and beauticians may keep their scissors, clippers, and combs under UV light to inhibit bacteria growth. There is evidence that HIV (the AIDS virus) is activated with increase UV exposure. Larvae of many species, such as fish, shrimp, crabs, and coral, are damaged by exposure to UV light. Increased UV exposure has the potential to affect many ecosystems in diverse ways, which would further impact human health.

6. Why is it more dangerous to be exposed to sunlight now than 50 years ago? The ozone layer has thinned, allowing more UV light to reach us. The recent thinning of the ozone shield is believed to be caused by chemicals containing chlorine and fluorine, mainly chlorofluorocarbons (CFCs) produced for aerosol cans and freon in refrigerators. An international agreement has prevented the increase of these chemicals in the stratosphere, but it will be years before the ozone shield will be reformed to its condition before the damage.

7. What can you do to protect yourself? In Australia, where light skinned people live under the ozone hole, children are required to wear hats during recess. It is important to protect the skin from UV, especially between the hours of 10 AM and 4 PM. Protect eyes by wearing UV-blocking sunglasses and hats. Lips can be protected by using lip balms, which contain sunscreens or sunblocks.

Extending the Activity

1. The paper test can be tried with UV blocking sunglasses. Use a lens from non-UV-blocking sunglasses and a lens from a UV blocker pair.

2. Invite a dermatologist or oncologist to speak with the students about health and ultraviolet light.

3. Discuss the practice of tanning and list the benefits/attraction versus negative impacts. Discuss the characteristics of skin and the different kinds of sun-related cancers. Discuss why society values certain 'looks' as beautiful.

4. Students can play Ozone Tag (in the Earth Systems section) to investigate how ozone is destroyed with man-made chemicals.

5. Brine shrimp may be ordered from biological supply companies (see Additional Resources). Students can carry out a longer-term experiment to test the effects of UV light on brine shrimp hatching.

6. Read and report on research about the effects of UV radiation on flora or fauna. E.g., Dr. Andrew Blaustein's work in the Cascade Mountains on UV and frog reproduction. *Proceedings of National Academy of Sciences*,Vol. 91, pp. 1791-1795.

7. A long-term experiment to see the effect of UV on plastics and other materials. Students may use a variety of plastics and nylon products. This damage causes great economic loss.

8. In 1987 at Montreal, most of the industrial nations met and signed the Montreal Protocol, which was the beginning of an international effort to eliminate the release of ozone depleting substances into the atmosphere.
Ozone Science 2007: A Canadian Contribution to the Twentieth Anniversary of the Montreal Protocol
http://www.ec.gc.ca/Publications/default.asp?lang=En&xml=0046FF7C-DABD-4949-AB36-F35D698BC0F3

Suggested Assessment

Students may write an essay that can be used to assess their knowledge and understanding of the objectives of this activity. The essay may be given the title of this activity, "UV and Me." In the context of the essay, students address the objectives listed at the beginning of the activity.

REFERENCES AND LINKS

http://uv.biospherical.com/
http://uv.biospherical.com/student/page3.html
NSF Polar Programs UV Monitoring Network

http://www.nws.noaa.gov/os/uv/
UV radiation awareness information

http://www.cpc.ncep.noaa.gov/products/stratosphere/uv_index/uv_nature.shtml

http://www.cancer.org/Cancer/CancerCauses/SunandUVExposure/skin-cancer-facts

U.S. Cancer Statistics Working Group. *United States Cancer Statistics: 1999–2006 Incidence and Mortality Web-based Report.* Atlanta (GA): Department of Health and Human Services, Centers for Disease Control and Prevention, and National Cancer Institute; 2010. Available at: http://www.cdc.gov/uscs.

http://ntp.niehs.nih.gov/ntp/roc/eleventh/profiles/s183uvrr.pdf

http://www.epa.gov/sunwise/doc/sunuvu.pdf

http://www.skincancer.org/Sunscreen/
information on how sunscreens work and how to choose one

Blaustein, A.R., B. Han, B. Fasy, J. Romansic, E.A. Scheessele, R.G. Anthony, A. Marco, D.P. Chivers, L.K. Belden, J.M. Kiesecker, T. Garcia, M. Lizana, and L.B. Kats. 2004. Variable breeding phenology affects the exposure of amphibian embryos to ultraviolet radiation and optical characteristics of natural waters protect amphibians from UV-B in the U.S. Pacific Northwest: comment. Ecology 85:1747–1754.

Palen, Wendy J., Daniel E. Schindler, Michael J. Adams, Christopher A. Pearl, R. Bruce Bury, and Stephen A. Diamond, 2004. Optical characteristics of natural water protect amphibians from UV-B in the U.S. Pacific Northwest. http://www.esajournals.org/doi/abs/10.1890/00129658(2002)083%5B2951:OCONWP%5D2.0.CO;2?journalCode=ecol

Hader, D-P. , H.D. Kumar, R.C. Smith and R.C. Worrest. 2007. Effects of solar UV radiation on aquatic ecosystems and interactions with climate change. Photochem. Photobiol. Sci., 2007, 6, 267–285 http://www.theozonehole.com/consequences.htm

OZONE

The activity "Ozone Tag" in the Earth Systems section of this activity manual will help students learn about the chemistry of ozone formation and the depletion of stratospheric ozone caused by some man-made chemicals.

U.S. Global Change Research Information Office http://www.gcrio.org/edu/index.htm

Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado at Boulder http://cires.colorado.edu/pubs/admin/annual/CIRES_Annual_Report_FY09.pdf

Brian Diffey 2004 Climate change, ozone depletion and the impact on ultraviolet exposure of human skin. *Phys. Med. Biol.* **49** R1

S. Solomon, The hole truth. What's news (and what's not) about the ozone hole, Nature, 2004, 427, 289–291.

Ozone Depletion section of Global Change Education Resource Guide, Lynn L. Mortensen, Editor, Office of Global Programs, National Oceanic and Atmospheric Administration, 1100 Wayne Avenue, Suite 1225, Silver Spring, MD 20910 http://www.eric.ed.gov:80/ERICWebPortal/search/detailmini.jsp?_nfpb=true&_&ERICExtSearch_SearchValue_0=ED402175&ERICExtSearch_SearchType_0=no&accno=ED402175

NASA FACTS. *Ozone: What is it, and why do we care about it?* (pamphlet), December 1993), Office of Public Affairs, Goddard Space Flight Center, Greenbelt, Maryland 20771 301 286-8955

Skin Care Under the Sun: The Importance of Sun Protection (pamphlet), American Academy of Dermatology, P.O. Box 2289, Carol Stream, IL 60132-2289 (847) 330-0230

Socioeconomic Data and Applications Center's (SEDAC) home page for the Stratospheric Ozone and Human Health Project http://sedac.ciesin.org/ozone/

http://sedac.ciesin.org/

RESOURCES FOR SUPPLIES

UV sensitive beads – available on-line at science experiment supply sites, or Steve Spangler http://www.stevespanglerscience.com/?gclid=COr_ga2KpawCFQtU7AodDT0GEw

Brine shrimp (Extending the Activity, #5) can be bought at almost any pet supply, or on-line.

VIDEO

Race to Save the Planet: "Only One Atmosphere"
An excellent video that addresses depletion of the ozone layer. It describes several climatic changes that have been linked to global warming and explains how the greenhouse effect warms the Earth.
Audio Visual/Media Center
Coe Library
University of Wyoming
Laramie, WY 82071
(307) 766-3184

Ozone, Ultraviolet Light, and You

Student Activity /Reading, Page 1

Prior to reading this part of the activity you will carry out a simple experiment directed by your instructor to observe possible effects of ultraviolet light. After the experiment, read these pages about ultraviolet light and life on earth.

Sunshine is made up of many different wavelengths, or colors, of light energy. Most living things need sunshine. Plants use light in photosynthesis, which is the process where light energy is converted and stored as sugars and starches. Animals need this food that plants provide. Sunshine helps human skin make the vitamin D that strengthens bones and teeth. Sunshine can affect our moods, too. If it is cloudy for too many days in a row, or dark for many months in northern regions, some people tend to get grumpy and depressed. Some people are affected more seriously with a condition called Seasonal Affective Disorder (SAD) and suffer depression, lethargy and overeating. Although sunshine is good for us, there are some types of energy rays in sunshine that can be harmful to us and other creatures.

One of the harmful waves of sunlight is called ultraviolet or UV light. We cannot see this light with our eyes, but there are instruments that can detect it. Many kinds of insects can see UV light. Some UV light is absorbed and deflected by window glass. Outside, without any protection, ultraviolet light can cause damage to our skin. Melanin is a brown pigment in human skin and the skin of many animals that builds up in quantity in response to UV exposure. This response is called tanning. Some people never tan but sunburn instead. A sunburn is when the skin becomes inflamed and is literally burned after it has been exposed to too much UV from sunlight. Exposure to UV over many years causes skin to wrinkle prematurely.

Ultraviolet light may cause skin cells to divide rapidly in an area. The condition may become malignant, commonly called cancerous. Exposure to UV may also affect how effective our immune system is and how well our bodies fight illness. After many years, UV can cause cataracts. Cataracts are a clouding of the clear lens of the eyes, making it difficult to see clearly.

The good news about this harmful part of sunlight is that most of it never reaches us. There is a chemical in the stratosphere called ozone. When UV penetrates the atmosphere, oxygen breaks apart and three atoms of oxygen recombine into ozone, or O_3. Ozone absorbs UV light, preventing most UV light from reaching the Earth's surface. In fact, the stratosphere is also called the ozonosphere, or ozone layer. There is some bad news about the ozone layer, though. The amount of ozone in the stratosphere has been decreasing in recent years. At some times of the year, there is actually a hole, or an area where there are relatively few ozone molecules in the ozone layer. The hole is over Antarctica and drifts over some populated lands, especially Australia and New Zealand. Even over New England, the ozone layer is thinner than it used to be. It becomes the thinnest in March. Especially during the spring, more UV light is reaching the surface of the earth.

Scientists discovered one of the causes of the decreased ozone levels in the 1970s. Chemicals called chlorofluorocarbons, or CFCs, were released from aerosol spray cans and the refrigerant freon and drifted up into the ozonosphere. CFCs react with ozone and break its chemical structure apart, destroying the ozone. In 1987 at Montreal, Canada, nations around the world signed an agreement, called the Montreal Protocol, to stop making CFCs and other ozone destroying chemicals. But the ozone will continue to decrease for most of the next century because of the CFCs and other ozone depleting chemicals that remain in the atmosphere. Another substance with ozone-depleting potential is halon, a compound of bromine, fluorine and carbon, used for decades to extinguish fires. Halon may not be manufactured any longer by law. Engineers and aviation specialists test various chemicals, searching for effective alternatives before the supply of halon runs out. Bromocarbons are also destructive to the ozone layer. Substances with ozone-depleting potential are listed by EPA: http://www.epa.gov/ozone/science/ods/classtwo.html. An ozone layer protection glossary is on the EPA website at http://www.epa.gov/ozone/defns.html.

Here are some facts and predictions:

There will be one million new cases of skin cancer worldwide this year, which is considered an epidemic.

Skin cancer is the leading cause of death in men and women between the ages of 25-30 in New Zealand.

Kangaroos and horses are now developing skin cancer while other animals are experiencing low reproductive rates.

Increased UV light has been linked to a recent loss of amphibians, worldwide.

For those people born in 1935: 1 in 1500 will get skin cancer.

For those people born in 1991: 1 in 105 will get skin cancer.

For those people born in 2000: 1 in 75 will get skin cancer.

Eye damage can be minimized by using UV-blocking sunglasses.

Skin damage can be minimized by using sunscreens and sunblocks with the recommended sun protection factor, or SPF.

ACTIVITY: UV LIGHT AND YOU
Source (modified): http://www.pbs.org/safarchive/4_class/45_pguides/pguide_404/4544_ozone.html#act1

Test the effects of exposure to ultraviolet radiation on living cells by simulating the ozone hole in the lab. Then, consider how this information might apply to you.
The increasing size of the ozone hole is a great concern for many. Use the following experiment to investigate what happens to living creatures when the protective ozone layer disappears. This is also a good project for a science fair.

MATERIALS

You will need:
- a selected organism to study, such as a plant, yeast culture, ant farm, algae, etc.
- a safe UV light source, such as the goggle box in your chemistry laboratory, tanning light, black light. (You can also use a fish tank with UV light, but the results won't be as dramatic.)
- a microscope, cell stains and slides (if desired).

PROCEDURE
1. Collect initial data on your organism of choice by making physical observations on the size, shape, color, mass,

texture, etc. Other suggestions include counting organisms or leaves, making microscopic slides for observation and measuring respiration.

2. Use a safe source of UV radiation, such as the enclosed goggle box in the chemistry lab. Expose your organism to the UV light.
3. Determine the variables that will control your experiment. Some suggested variables include:
   - overall length of exposure
   - short bursts versus longtime exposure
   - type of UV bulb used
   - length of time of the overall study
   - type of organism – and stage of development, e.g., eggs, sperm, developing animals such as tadpoles
   - type of food and liquid supplied
4. Try protecting some of the organisms from UV by devising a 'shield', e.g., sunblock on a plastic or glass sheet, or commercially sold UV-protective shading.
5. Predict what will happen. You should see some changes over time, especially in cell structure.

QUESTIONS

In addition to your formal write-up of this lab, consider:

1. Based on your studies, could you hypothesize what might happen to human cells under the same condition?
2. What concerns about UV light and the ozone layer do you have after completing this investigation?
3. Evaluate your lifestyle. Can you do anything to change what is happening in the atmosphere or do you feel the dilemma of the ozone layer will not affect you? What action will you take the next time you are participating in an outdoor activity? What will you change in your lifestyle or your family's lifestyle that can affect the ozone layer?
4. Find out more about how the ozone layer protects us from UV light. What reactions are going on when the UV light hits the ozone?

CRITICAL THINKING

What happens when the protective ozone layer disappears? Direct UV radiation from the sun reaches the earth's surface. Dangerous levels of UV radiation can weaken the immune system, cause cataracts, skin cancer and wrinkling. Sunscreens and blocks provide only some protection.

- What impact could continued ozone depletion have on a national health care system?
- UV radiation can interfere with photosynthesis, causing lower crop yields. Discuss how reduced quantities of produce will affect the economy. Will this have an impact on the buying and eating habits of your family?
- Radiation has been found to slow the growth of phytoplankton, the mainstay of the ocean food chain. How will this affect marine life? What might increased levels of radiation do to the human food chain? Should we act now and take protective measures or wait until we are secure in our scientific findings?
- Ozone exists in huge quantities around major cities as a component of smog. Describe the reaction for producing ozone (smog) in the atmosphere. Why doesn't ozone at ground level protect the way the ozone layer does? Can you suggest ways in which we can replenish the ozone layer in the stratosphere?

LAB NOTES

- Use this activity to enrich your study of chemical elements when you work with the periodic table. You can also apply the concepts to environmental science.
- The experiment to monitor exposure to UV light can be used as a biochem lab or as a long-term research activity, even as a science fair project. The critical thinking questions can be used with a range of subject areas.