

No Littering O-Zone:

How Rising Ozone Levels Affect Tree Growth

Meet the Scientists!



Dr. Liu

Ecologist (Ē kôl ō jist)

The great thing about being an ecologist is you are always on the way to discovering the secrets of nature. To answer a scientific question, you need to design an experiment, collect and interpret the experimental data, and then draw a conclusion. During those processes, I learn new knowledge. Most importantly, I can help keep our planet healthy by sharing my findings with other scientists and the public.



Dr. King

Forest Ecologist and Physiologist
(Fiz ē ôl ō jist)

There are so many rewards to a career in science that it is difficult to pick a single favorite experience. The thing I like best about it is the ability to have an impact, that is, to do something good for people or the environment. Every time I publish a scientific paper or help a student to become a scientist, I feel that I help the world to be a better place. Also, I work on many different questions in many different places, so my work is always interesting! In the picture I am giving a talk to foresters in North Carolina.

Meet the Scientists!

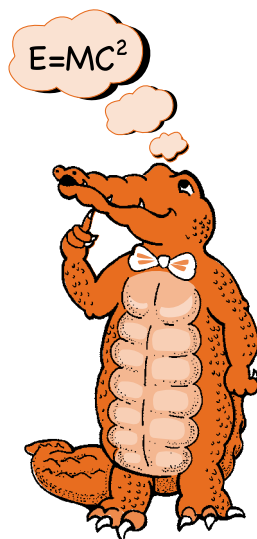


Dr. Giardina
Forest Ecologist

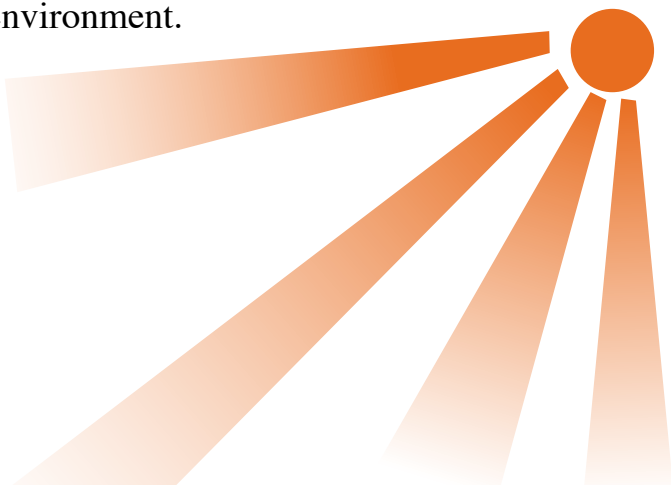
My favorite science experience was traveling to the Central American country of **Belize** (beh lez) and wandering in a really cool and really big cave called the **Rio Frio** (re o fre o) cave near the western border with **Guatemala** (gwa tuh mal uh). The mouth of the cave is covered all around its rim with the most amazing trees. There were hundreds of types of giant trees. The roots of the trees were ringed all along the outside of the rim of the cave, and the cave was full of bats.

Thinking About Science

Scientists want to discover the correct information about our world. To do this, they often set up experiments. They want these experiments to be as close to the real world as possible. In this study, the scientists wanted to know how increasing the amount of **ozone** (o zon) might affect some types of trees. You will learn about ozone in the next section.



One way to find out how ozone affects trees might be to put potted trees into a room. Then the scientists could increase the amount of ozone in the room. Does this seem like the real world to you? It did not seem that way to the scientists either! Instead, the scientists planted trees outside in a special area. They constructed towers that released ozone into the wind. The wind carried the ozone to the trees. This allowed scientists to observe how the trees respond to ozone in a more natural environment.



Thinking About the Environment

Have you heard about the chemical ozone? Ozone is a gas that contains oxygen. Ozone is found in the atmosphere. Sometimes ozone can be helpful and sometimes it is harmful.



The atmosphere has different layers (**figure 1**). The **troposphere** (**trop o sfer**) is the layer of atmosphere closest to Earth

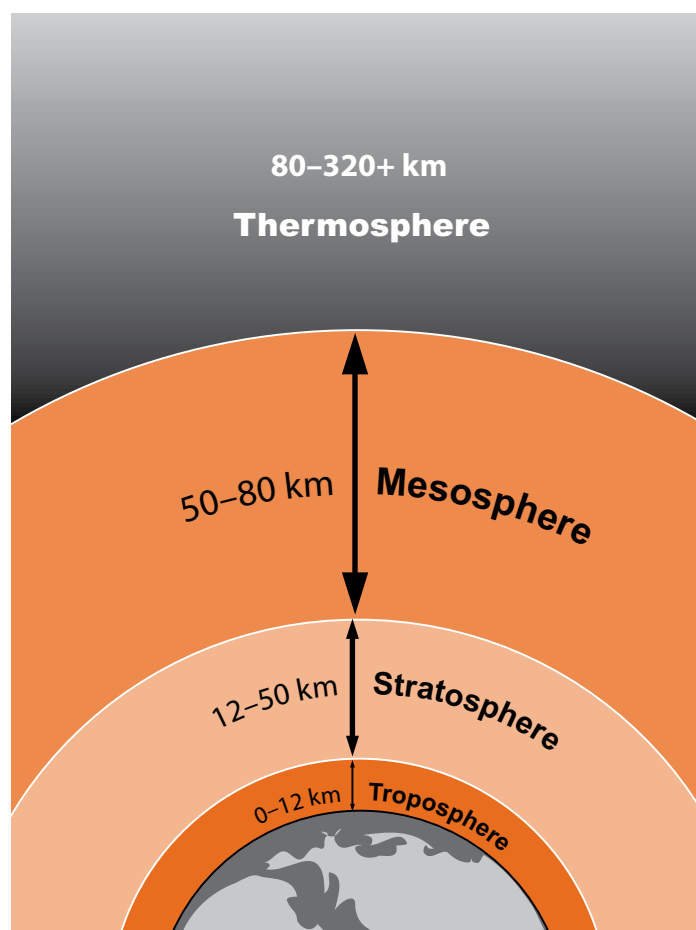


Figure 1. Look at the diagram of Earth's atmosphere. What do you notice about the troposphere compared to the other layers?

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	ng	as in sing

Accented syllables are in **bold**.

(figure 2). When ozone is found in the troposphere, it is harmful. Ozone is the main ingredient of **smog** (smawg). Smog is polluted air and is a danger to human health.

Ozone is also found in the **stratosphere** (strat o sfer). The stratosphere is a higher level of the atmosphere (**see figure 1**). In the stratosphere, ozone provides a layer of protection from the sun's harmful rays. This example shows how ozone can also be helpful.

You can see that ozone can both protect and harm life on Earth. Humans can create

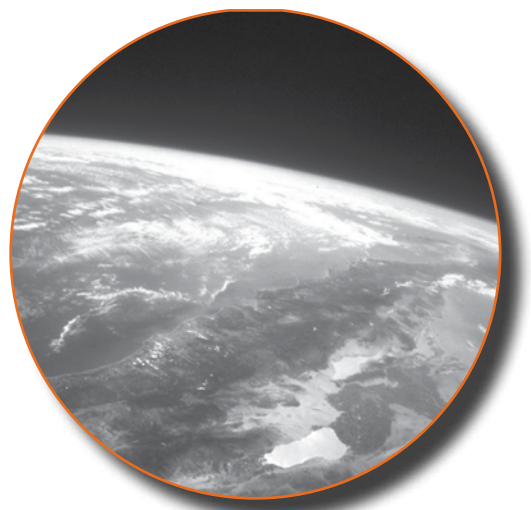


Figure 2. This is a picture of Earth's atmosphere from space. The atmosphere is the light colored band. Sally Ride, the first woman in space, took this picture.

Photo is courtesy of NASA.

more ozone. For example, **fossil fuels** (fô

- ul
- fyools

) are fuels that are formed from the remains of animals from the past (**figure 3**). Gasoline is an example of a fossil fuel. When people burn fossil fuels, the amount of ozone in the troposphere rises. The increase in ozone impacts humans as well as other living things. The scientists in this study wanted to know how trees might be affected by rising levels of ozone in the troposphere.

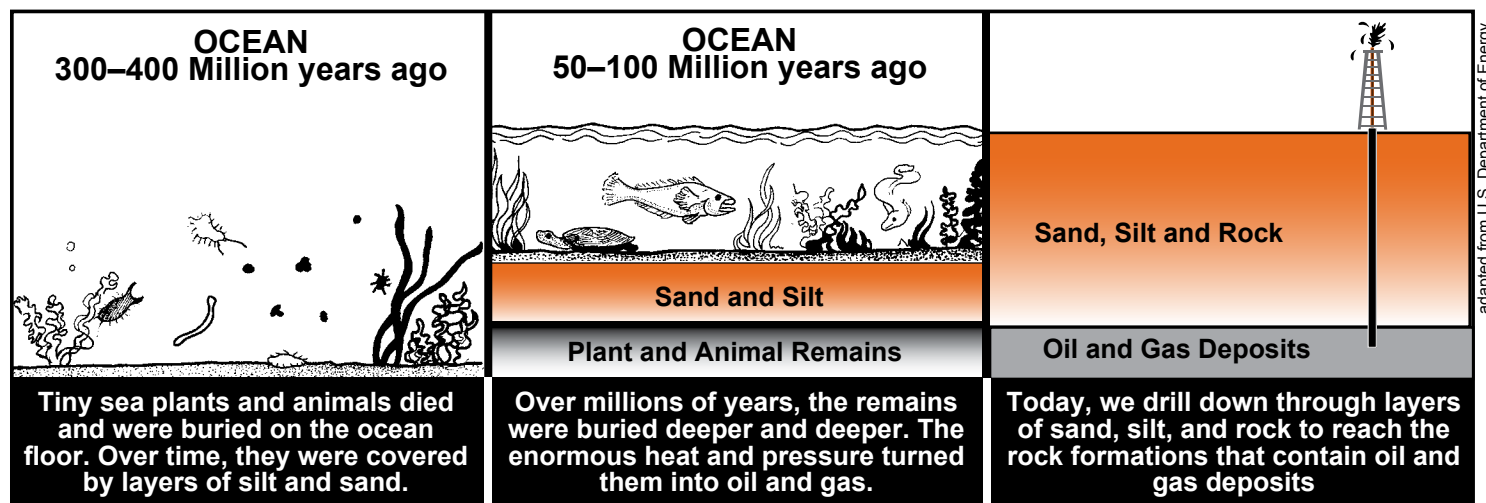


Figure 3. This diagram shows you how fossil fuels are made. Do you think this process is quick or slow? Why?

Introduction

Every fall, **deciduous** (de sij oo us) trees drop their leaves to the forest floor. Deciduous trees are trees that lose their leaves in the fall or winter. These fallen leaves are called **leaf litter** (lef lit ür) (**figure 4**). After a while, the fallen leaves begin to break down.



Figure 4. This is a picture of leaf litter. What do you notice about it?

When leaf litter breaks down, it provides **nutrients** (noo tre ents) for the soil (**figure 5**). Nutrients are any substance found in foods that are necessary for plants and animals. This movement of nutrients from leaves to the soil is important. It helps new plants grow. Two of the main nutrients from fallen leaves are carbon and nitrogen. These nutrients are important to continue the cycle of plant growth on Earth.



Figure 5. Leaves have fallen around this plant. The leaf litter provides nutrients and protection for the plant.

Nutrients that go into the soil are affected by two things. First, the number of leaves that grow every season is important. Second, what the leaves are made of is important, too. If something happens to change the number of leaves on trees or their makeup, the soil might be changed as well.

In recent years, humans have been burning more and more fossil fuels. Fossil fuels are oil, natural gas, and coal. One of the extra products created by burning fossil fuels is ozone. Since the level of ozone is rising, the scientists wanted to know how this affects how trees grow. Tree growth starts in leaves. Therefore, scientists started by looking at the leaves. They looked at how many leaves were produced. They also looked at the amount of nutrients in the leaves.

Reflection Section

➔ In your own words and in the form of a question, state what the scientists wanted to learn.

➔ Think about trees growing inside a building and trees growing outside. Name three things that make observing trees outside more natural than observing them inside.

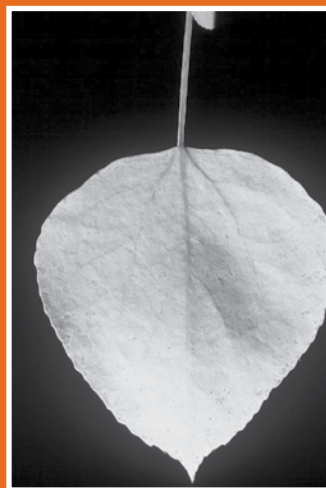
Method

The study took place near Rhinelander, Wisconsin (**figure 6**). The scientists divided a large area of land into three blocks. In each block, they planted small areas with aspen and birch trees. These trees are fast-growing (**figures 7a and 7b**). The scientists waited until the trees were six years old to take their measurements. They did this because they wanted information about older trees where the tops of the trees are touching (**figure 8**).

In one area, the scientists did not spray ozone gas into the trees. The scientists used this area as a **control** (kān trōl). A control is something used for comparison when checking the results of an experiment. In this experiment, the control is an area where no ozone is sprayed. In the second area, the



Figure 6. Rhinelander, Wisconsin is located in the northern portion of Wisconsin.



7a



7b

Figure 7a and 7b. Aspen (7a) and birch (7b) leaves.



Figure 8. Notice how the tops of trees are touching in this tree canopy.

scientists sprayed ozone gas into the trees (figures 9 and 10). The scientists sprayed these trees for six years until it was time to measure them.

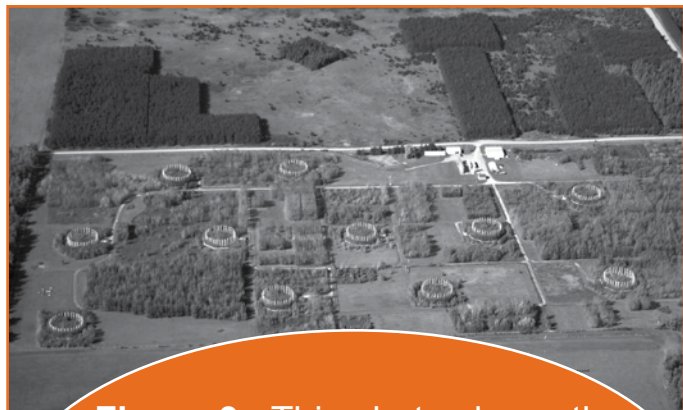


Figure 9. This photo shows the experimental site. The sprayers can be seen as small ovals in this photo. These sprayers sprayed ozone into the wind. The wind carried the ozone to the trees.

The scientists placed baskets under the trees in each of the areas. Baskets were placed in a circle in the middle of the trees. The baskets were evenly spaced. The baskets caught leaf litter falling from the trees. The contents of the baskets were collected every two weeks. This continued from June through October until all leaves had fallen off the trees.

After collecting the leaf litter, the scientists dried it. Drying it removed any moisture. The scientists weighed the dried litter. This helped the scientists determine how much living material was in the leaf litter and how much leaf litter was produced.

Next, the type and amount of nutrients in the leaf litter were measured. This helped scientists know how ozone affected the



Figure 10. This is a close up photo that shows the circle of trees with the ozone sprayers.

leaves. Finally, the scientists compared the measurements of leaves collected from trees that had not been sprayed with ozone gas with leaves from trees that had been sprayed with ozone gas.



➡ When people rake leaves in the fall, they take nutrients away that could one day become a part of the soil. What do people do to their lawns to make up for this?

➡ Do you think scientists must have patience to do some of their experiments? What evidence of this can you find in the "Method" section?

Number Crunches

If the scientists collected the leaf litter every two weeks from the beginning of June until the end of October, how many times in all did they collect the leaf litter?

Findings

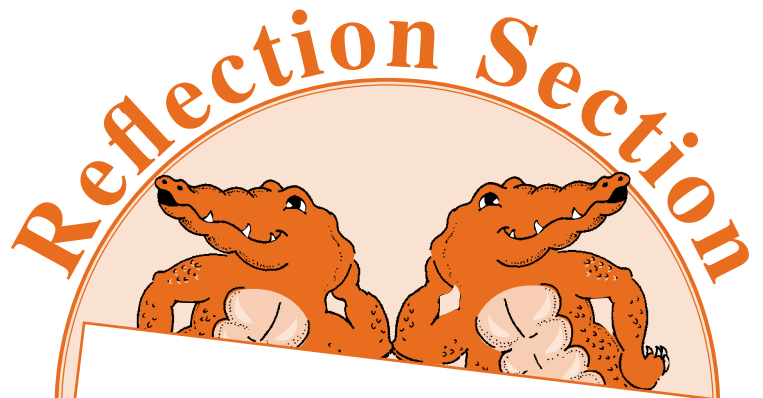
The scientists compared the trees sprayed with ozone to the trees growing under normal conditions. Trees growing in higher levels of ozone had lower levels of living material in their leaf litter. Overall, the amount of carbon and nitrogen was lower in leaf litter from trees grown in higher ozone levels. In addition, the trees also had fewer leaves.



- ➔ Based on the findings, do you think that higher levels of ozone would be good for trees and other plants growing in the forest? Why or why not?
- ➔ If less leaf litter is produced, would growing plants be helped or hurt? Explain your answer.

Discussion

In areas with higher ozone, the way leaves were made caused the leaf litter to break down more slowly. Additionally, smaller amounts of leaf litter were produced. Therefore, there were fewer nutrients available to growing plants. The leaf litter also contained less carbon and nitrogen. These nutrients are important for the plant growth cycle.



- ➔ Based on the findings and discussion in this study, do you think humans should try to reduce the amount of ozone being produced? Why or why not?
- ➔ What is the answer to the scientists' question? Reread the end of the "Introduction" if you have forgotten the scientists' question.

FACTivity

The question you will explore in this FACTivity is:
How does ozone in the troposphere and stratosphere impact Earth?

The method you will use to do this is:

The class will divide into groups of four students. One half of each group will study the impact of ozone that occurs close to Earth, in the troposphere. The other half will study the impact of ozone that occurs in the upper atmosphere, in the stratosphere. You can do your research in the library and on the internet.

Gather information about the effects of ozone, and how human activities are affecting

Some search terms each team might use:

Tropospheric ozone team

Tropospheric ozone
Ozone pollution

Stratospheric ozone team

Stratospheric ozone
Ozone UV radiation

ozone. After each team of two students has collected their information, the team should summarize the information about ozone. In the summary, include information about where the ozone occurs. Each group of four students should then share and compare the summarized information within their group. As a group, discuss how ozone is both beneficial and harmful. Compare ozone's benefit and harm with where the ozone is found in each situation. Develop recommendations about what people can do in relation to ozone in the troposphere and in the stratosphere. Document your learning by creating a poster, which you will share with the class.

Hold a class discussion about what each group learned about ozone. Compare ozone in the troposphere with ozone in the stratosphere. What are the differences and similarities?

Useful Web Resources:

EPA's Sunwise Kids Ozone Layer information

http://www.epa.gov/sunwise/kids/kids_ozone.html

National Geographic for Kids Ozone Article

<http://kids.nationalgeographic.com/Stories/SpaceScience/Ozone>

Environmental Education For Kids—Ozone Layer

<http://www.dnr.state.wi.us/Org/caer/ce/eeek/earth/air/ozonlayr.htm>

Adapted from: Liu, L., King, J.S., and Giardina, C. P. (2005). Effects of elevated concentrations of atmospheric CO₂ and tropospheric O₃ on leaf litter production and chemistry in trembling aspen and paper birch communities, *Tree Physiology*, 25: 1511-1522.
<http://www.treesearch.fs.fed.us/pubs/13345>.



If you are a PLT-trained educator, you may use PLT Activity #73, "Waste Watchers," as an additional resource.