Air Chemistry in the Garden

***Grade:** 8 | **Time:** 2-3 60 minute periods*

Standards:
Georgia Performance Standards in Science
S8CS2.a; S8CS4.b, c; S8CS9.b, e, f; S8P1.a, b, c, f, g; S8P5.a
Next Generation Science Standards
PS1.A, PS1.B, PS2.B
Common Core Literacy Standards
ELACC6-8RST3, ELACC6-8RST4

Supplies:
for Ozone Bio-monitoring
per group of 4 (8 groups per class)
BYO: 1 milkweed or other bio-monitoring plant
BYO: 1 meter stick or tape measure
BYO: 1 clipboard, data form, and computer

For Making a Particle Collector
Per Group of 4 students (8 groups per class)
1 Index card
1 sheet of 1 cm chart paper
1 pc double sided tape (approx. 20 in long)
Bring Your Own
BYO: glue stick
BYO: 12 " string or paper clip to make hanger
BYO: single hole punch

For Making a Model Electrostatic Precipitator

Per Student
½ Teaspoon ground herb or spice (not pepper)
1 balloon

For Making a Model of Cyclone Hopper
Per student or per group of 4
1 3-oz paper cup
1 jar petroleum jelly
1 sharpened pencil or bamboo skewer

Garden Connection:
Plant species sensitive to ozone, such as milkweed, will be planted in the garden to serve as indicators of air pollution. (Other species, including plants that may already exist on school grounds, may be substituted for milkweed). Dried herbs or spices from the garden may be used to represent pollution particles in the activity making electrostatic precipitators.

Technology:
Students will make a model of an electrostatic precipitator and predict its effectiveness.

Overview

Students will conduct an ozone bio-monitoring citizen science project and other investigations of air pollution in the vicinity of the school garden. Students will also create a classroom air-filtering garden and explore ways to reduce air pollution using an online interactive app.

Essential Questions

How can I estimate ozone air pollution levels by observing plants in the garden? What causes air pollution and how does it affect organisms and ecosystems? What can be done to reduce or mitigate air pollution?

Engage

Students will create particle pollution testers and make models of electrostatic precipitators and bag hoppers to investigate this form of air pollution.

Explore

Students will monitor ozone-sensitive plants for indications of this form of air pollution and report data as part of a citizen science project. Students will make Schönbein strips to detect the presence of ground-level ozone.

Explain

Students will explain the impact that air pollutants, and particularly ground-level ozone, have on organisms and on an ecosystem. Then students will argue from evidence regarding whether the air is polluted or healthy.

Environmental Stewardship

Students will create an ozone monitoring garden using sensitive plant species to detect air pollution OR create an indoor air-purifying garden, using plants that hyper-accumulate toxins and chemicals.

Evaluation

A rubric is provided to assess student mastery of performance expectations.

Extend

Students may make a model of a cyclone hopper to see how it effective it may be at reducing particle pollution.

Standards

GEORGIA PERFORMANCE STANDARDS IN SCIENCE

S8CS2. Students will use standard safety practices for all classroom laboratory and field investigations.

a. Follow correct procedures for use of scientific apparatus.

S8CS4. Students will use tools and instruments for observing, measuring, and manipulating equipment and materials in scientific activities utilizing safe laboratory procedures.

b. Use appropriate tools and units for measuring objects and/or substances.
c. Learn and use standard safety practices when conducting scientific investigations.

S8CS9. Students will understand the features of the process of scientific inquiry. Students will apply the following to inquiry learning practices:

b. Scientific investigations usually involve collecting evidence, reasoning, devising hypotheses, and formulating explanations to make sense of collected evidence.
e. Accurate record keeping, data sharing, and replication of results are essential for maintaining an investigator's credibility with other scientists and society.
f. Scientists use technology and mathematics to enhance the process of scientific inquiry.

S8P1. Students will examine the scientific view of the nature of matter.

a. Distinguish between atoms and molecules.
b. Describe the difference between pure substances (elements and compounds) and mixtures.
c. Describe the movement of particles in solids, liquids, gases, and plasmas states.
f. Recognize that there are more than 100 elements and some have similar properties as shown on the Periodic Table of Elements.
g. Identify and demonstrate the Law of Conservation of Matter.

S8P5. Students will recognize characteristics of gravity, electricity, and magnetism as major kinds of forces acting in nature.

a. Recognize that every object exerts gravitational force on every other object and that the force exerted depends on how much mass the objects have and how far apart they are.

NEXT GENERATION SCIENCE STANDARDS

PS1.A: Structure and Properties of Matter
Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2, MS-PS1-3)

PS1.B: Chemical Reactions
The total number of each type of atom is conserved, and thus the mass does not change. (MS-PS1-5)

PS2.B: Types of Interaction
Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively). (MS-PS-5)

COMMON CORE LITERACY STANDARDS

ELACC6-8RST3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.

ELACC6-8RST4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.

Teacher Background Information

Atmospheric Pollution

- Many forms of atmospheric pollution affect human health and the environment at levels from local to global. These contaminants are emitted from diverse sources, and some of them react together to form new compounds in the air. Industrialized nations have made important progress toward controlling some pollutants in recent decades, but air quality is much worse in many developing countries, and global circulation patterns can transport some types of pollution rapidly around the world.
- Four types of processes affect air pollution levels:
  - Emissions: Chemicals are emitted to the atmosphere by a range of sources. Anthropogenic emissions come from human activities, such as burning fossil fuel. Biogenic emissions are produced by natural functions of biological organisms, such as microbial breakdown of organic materials. Emissions can also come from nonliving natural sources, most notably volcanic eruptions and desert dust.
  - Chemistry: Many types of chemical reactions in the atmosphere create, modify, and destroy chemical pollutants.
  - Transport: Winds can carry pollutants far from their sources, so that emissions in one region cause environmental impacts far away. Long-range transport complicates efforts to control air pollution because it can be hard to distinguish effects caused by local versus distant sources and to determine who should bear the costs of reducing emissions.
  - Deposition: Materials in the atmosphere return to Earth, either because they are directly absorbed or taken up in a chemical reaction (such as photosynthesis) or because they are scavenged from the atmosphere and carried to Earth by rain, snow, or fog.
- Air pollution trends are strongly affected by atmospheric conditions such as temperature, pressure, and humidity, and by global circulation patterns. For example, winds carry some pollutants far from their sources across national boundaries and even across the oceans. Transport is fastest along east-west routes: longitudinal winds can move air around the globe in a few weeks, compared to months or longer for air exchanges from north to south.
- Primary air pollutants are emitted directly into the air from sources. They can have effects both directly and as precursors of secondary air pollutants (chemicals formed through reactions in the atmosphere).
- Sulfur dioxide (SO2) is a gas formed when sulfur is exposed to oxygen at high temperatures during fossil fuel combustion, oil refining, or metal smelting. SO2 is toxic at high concentrations, but its principal air pollution effects are associated with the formation of acid rain and aerosols. SO2 dissolves in cloud droplets and oxidizes to form sulfuric acid (H2SO4), which can fall to Earth as acid rain or snow or form sulfate aerosol particles in the atmosphere.
- Nitrogen oxides (NO and NO2, referred together as NOx) are highly reactive gases formed when oxygen and nitrogen react at high temperatures during combustion or lightning strikes. Nitrogen present in fuel can also be emitted as NOx during combustion. Emissions are dominated by fossil fuel combustion at northern mid-latitudes and by biomass burning in the tropics. In the atmosphere NOx reacts with volatile organic compounds (VOCs) and carbon monoxide to produce ground-level ozone through a complicated chain reaction mechanism. It is eventually oxidized to nitric acid (HNO3). Like sulfuric acid, nitric acid contributes to acid deposition and to aerosol formation.
- Carbon monoxide (CO) is an odorless, colorless gas formed by incomplete combustion of carbon in fuel. The main source is motor vehicle exhaust, along with industrial processes and biomass burning. Carbon monoxide binds to hemoglobin in red blood cells, reducing their ability to transport and release oxygen throughout the body. Low exposures can aggravate cardiac ailments, while high exposures cause central nervous system impairment or death. It also plays a role in the generation of ground-level ozone.
- Volatile organic compounds (VOCs), including hydrocarbons (CxHy) but also other organic chemicals are emitted from a very wide range of sources, including fossil fuel combustion, industrial activities, and natural emissions from vegetation and fires. Some anthropogenic VOCs such as benzene are known carcinogens.

- VOCs are also of interest as chemical precursors of ground-level ozone and aerosols. The importance of VOCs as precursors depends on their chemical structure and atmospheric lifetime, which can vary considerably from compound to compound. Large VOCs oxidize in the atmosphere to produce nonvolatile chemicals that condense to form aerosols. Short-lived VOCs interact with NOx to produce high ground-level ozone in polluted environments. Methane (CH4), the simplest and most long-lived VOC, is both as a greenhouse gas and as a source of background tropospheric ozone. Sources of methane include natural gas production, coal mining, livestock, and rice paddies.

- **For more information about atmospheric pollution, see the websites below:**
  - » http://www.learner.org/courses/envsci/unit/pdfs/unit11.pdf
  - » http://ncar.ucar.edu/learn-more-about/pollution
  - » http://www.conserve-energy-future.com/causes-effects-solutions-of-air-pollution.php
  - » http://www.explainthatstuff.com/air-pollution-introduction.html
  - » http://www.lenntech.com/faq-air-pollution.htm
  - » http://www.nature.nps.gov/air/AQBasics/sources.cfm

- Secondary pollutants form when primary pollutants react in the atmosphere. Ground-level ozone (O3) is a secondary air pollutant, toxic to both humans and vegetation. A naturally occurring form of oxygen with three atoms instead of the two in atmospheric oxygen, ozone can be found in the lower stratosphere (about 15–25 miles, or 25–40 kilometers, above Earth). There it intercepts ultraviolet light from the Sun that could otherwise prove deadly to people, animals, and plants. Unfortunately, pollution is creating two ozone-related problems:
  - » Certain pollutants deplete ozone in the stratosphere, exposing us to unhealthy levels of ultraviolet radiation.
  - » Human-related emissions are spurring the formation of harmful ground-level ozone and smog.
- Ground-level ozone is one of the most harmful forms of pollution, causing respiratory problems and damaging plants.

- Ozone is formed in surface air (and more generally in the troposphere) by oxidation of VOCs and carbon monoxide in the presence of NOx and sunlight. Note that this is not a pollutant that comes straight out of a tailpipe or smokestack. NOx and OH are catalyst: they speed up the rate of ozone generation without being consumed.

- The word "ozone" comes from the Greek word ozein—to smell. That's the name its discoverer, German scientist Christian Schönbein gave it in 1839, to describe the acrid-smelling gas (the same smell when it starts to rain).

- Schönbein wanted to show that this triatomic form of oxygen (O3) was a natural part of the atmosphere, not just a laboratory-concocted curiosity. He devised a method to measure ozone that turned out to be both easy to do and sensitive even to low levels of O3 in the surroundings. His invention is known today as the Schönbein paper.

- Today, scientists are fascinated by the laboratory findings of 19th and early 20th century chemists who used this sensitive paper to record ozone levels in Schönbein units. Their records are proving to be particularly useful for determining long-range trends of ozone concentrations in the air we breathe. To make meaningful comparisons, researchers are carefully examining the experimental methods used by these early scientists so that they can duplicate them in current studies—an excellent argument for keeping good laboratory records! You never know who might need the details about how you performed an experiment and obtained your results.

- Old Schönbein paper results reveal dramatic changes in Earth's atmosphere. Ground-level ozone appears to have increased at least 300% since preindustrial times. Ground-level ozone is toxic to living organisms, interacts with living tissue, and donates oxygen atoms freely in a process known as oxidation that accelerates cellular aging. Breathing too much ozone impairs lung capacity, and sets us up for illnesses such as asthma. Several plant species respond to high ozone levels with lowered rates of photosynthesis and productivity. Human activities (including vehicle emissions that react with other substances in sunlight) are responsible for ground-level ozone.

- **For more information about ground level ozone and ozone monitoring, see the websites below:**
  - » http://www.handsontheland.org/data/documents/ozone_monitoring_guide_2011.pdf
  - » http://www.learner.org/courses/envsci/unit/pdfs/unit11.pdf
  - » http://ncar.ucar.edu/learn-more-about/pollution
  - » http://www.epa.gov/groundlevelozone/
  - » http://www.gsmit.org/CSOzoneGarden.html

- **Resources about ozone and smokestacks:**
  - » http://www.explainthatstuff.com/electrostaticsmokeprecipitators.html
  - » http://www.nist.gov/pml/div685/grp02/scale-model-smokestack.cfm
  - » http://science.howstuffworks.com/environmental/green-science/clean-coal.htm
  - » http://science.howstuffworks.com/environmental/green-science/ozone-pollution.htm
  - » http://science.howstuffworks.com/environmental/green-science/carbon-capture.htm

Biomonitoring

- Biological monitoring (or bio-monitoring) is the use of sensitive organisms to provide information on the quality or "health" of an ecosystem. Biomonitoring of air pollution with plants has been a common practice for many decades. Some plant species are sensitive to specific single pollutants or to mixtures of pollutants. Those species or cultivars are likely to be used in order to monitor the effects of air pollutants as bioindicator plants. They have the great advantage to show clearly the effects of phytotoxic compounds present in ambient air.
- Many plants are useful as bioaccumulators and the choice of species depends on the aims of bio-monitoring. Is monitoring environmental pollution, as such, the main purpose or is it to study the impact on ecosystems or the transfer of pollutants to the food chain? Mosses and lichens accumulate heavy metals and other compounds very efficiently because of their large specific surface and slow growth. As such they serve mostly as passive biomonitors to provide an indication of the pollutant impact at the ecosystem level. On the other hand, field crops and vegetables can serve as an intermediate step to detect effects on food quality and safety. Bioaccumulators are not only used to measure deposits of heavy metals but also radionuclides, polycyclic aromatic hydrocarbons, dioxins and all kinds of aerosols, which can also be accumulated efficiently.
- For more information on biomonitoring with plants, see the websites below:
  - http://dnr.wi.gov/org/caer/ce/eek/earth/field/biomon.htm
  - http://www.fia.fs.fed.us/library/fact-sheets/p3-factsheets/Ozone.pdf
  - http://isebindia.com/05_08/05-04-1.html
  - http://www.sciencedaily.com/releases/2008/04/080425081709.htm
  - http://dnr.wi.gov/org/caer/ce/eek/teacher/milkweedmonitoring/text.pdf
  - http://www-pub.iaea.org/MTCD/publications/PDF/te_1338_web/t1338_part1.pdf
  - http://www.pathfinderscience.net/ozone/cbackground.cfm
- **For information on designing an ozone biomonitoring garden, see the websites below:**
  - » http://www.handsontheland.org/data/documents/ozone_monitoring_guide_2011.pdf
  - » http://www.onestl.org/toolkit/list/practice/ozone-garden
  - » http://www.gsmit.org/downloads/NPSOzoneGardenStudyDesign.pdf
  - » http://www.gsmit.org/downloads/OzoneInstructionsActivities.pdf
  - » http://www.earthsciweek.org/classroom-activities/plant-ozone-monitoring-garden
  - » https://www.popularresistance.org/an-ozone-garden-tells-you-about-the-air-quality-around-your-home/
- **List of biomonitoring plants:**
  - » http://www.handsontheland.org/data/documents/ozone_monitoring_guide_2011.pdf (see p. 15)
  - » http://www.nature.nps.gov/air/Pubs/pdf/BaltFinalReport1.pdf (see pp. 11-13)
- **List of indoor air filtering plants:**
  - » http://en.wikipedia.org/wiki/NASA_Clean_Air_Study
- Air pollution trends are strongly affected by atmospheric conditions such as temperature, pressure, and humidity, and by global circulation patterns. For example, winds carry some pollutants far from their sources across national boundaries and even across the oceans. Transport is fastest along east-west routes.

Teacher Preparation

Acquire supplies and materials needed for lesson activities. Make copies for students of data reporting forms for Hands on the Land or Tremont zone bio-monitoring project https://www.handsontheland.org/data/documents/ozone_monitoring_guide_2011.pdf pages 43 and 46

Engage

Collect Atmospheric Particle Pollution

http://www.learner.org/courses/envsci/support/guide_unit11.pdf (see p. 152)

» Introduction: This activity allows students to monitor particle pollution in the air and can be used to compare conditions at different locations. Examining the particles under a microscope can extend this activity.

» Materials per person or per team: Index card, double stick tape (4 inch piece), chart paper, glue stick

» Procedure for Making a Particle Pollution Catcher

1. Cut a 4” x 6” piece of 1 sq cm chart paper to cover an index card and glue them together.
2. Use a hole punch to make one hole in a corner of the card and attach a string.
3. On the back of the card, write the date and location where the particle pollution catcher will be hung.
4. Outline a 10 cm x 10 cm square on the card.
5. Within the outlined square, randomly select 10 smaller squares and outline them.
6. Random selection may be accomplished by writing numbers 1 through 10 on small pieces of paper, folding them, and drawing numbers to represent x and y coordinates within the larger square (for example, drawing a 3 and then a 4 would mean: 3rd row, 4th column), and outlining each of ten corresponding small squares.
7. Cover the larger 10 cm x 10 cm section of chart paper with double stick tape.
8. Hang the particle catcher and let it remain in place for at least one day.
9. Take the particle catcher down and examine it with a hand lens or field microscope.
10. Count the number of particles observed in each of the ten outlined 1 cm square sections, and average
11. Compare results with students who have hung particle catchers in different locations
12. Go to http://scorecard.goodguide.com/ and enter the zip code where each particle catcher was hung, to find out which are the major pollutants in the area

Make a Balloon Model of an Electrostatic Precipitator, for Mitigating Particle Pollution

https://www.teachengineering.org/view_activity.php?url=collection/cub_/activities/cub_air/cub_air_lesson10_activity2.xml

» Summary: Students will observe and discuss a simple balloon model of an electrostatic precipitator

» Engineering Connection: Environmental and mechanical engineers invent new techniques to reduce industrial air pollution. In an electrostatic precipitator, a static charge attracts pollution particles to electrified plates of metal, similar to how static electricity in clothing attracts bits of lint. This technique works well on emissions from power plants, steel or paper mills, smelters and cement plants.

» Materials (per student): ½ teaspoon ground dried herb or spice from the garden; 1 balloon.

» Procedure:

1. Give each student a balloon and dried herbs or ground spices from the garden (oregano, parsley, cinnamon, etc).
2. Students should predict what percentage of particles will be collected by the electrostatic precipitator model.
3. Tell students to blow up their balloons and rub them on their hair or a piece of cloth.
4. Hold the balloon over the spice or herb (representing particulate pollution). Even without touching the particles, static electricity will cause the balloon to pick up the particles.
5. Discuss student observations in comparison to their predictions. Does the electrostatic precipitator remove all of the particulates? (Answer: No, not all of them. Real electrostatic precipitators are about 98% efficient. How does this compare to the efficiency of a wet scrubber? Which one is better? (Answer: A wet scrubber is 94% efficient, so precipitators are more efficient). If the precipitators are more efficient, why would you ever want to use a wet scrubber? (Answer: Wet scrubbers work better on pollutants in gaseous form)

» For upper grades, add a math component. Give students a number of particulates, and have them calculate how many are cleaned from the air using electrostatic precipitators with 98% efficiency. For example, if 100,000 particulates went through this electrostatic precipitator, about 100,000 x .98 = 98,000 would be removed, and 2,000 would remain.

Explore

Citizen science projects to monitor air pollution due to ground level ozone

» Hands on the Land http://www.handsontheland.org/environmental-monitoring/ozone-bio-monitoring.html
» “Ozone Garden” from the Great Smoky Mountains Institute at Tremont: http://www.gsmit.org/CSOzoneGarden.html

- Have students write in their science journals what they know about pollution, describe as many types of pollution as they can, and tell how pollutants affect different organisms in ecosystems. Also, address any misconceptions about stratospheric ozone (desirable) vs ground level ozone (undesirable pollutant; smog ingredient).

- Choose an ozone-sensitive species to monitor such as Tall and Common Milkweed, Cutleaf Coneflower, Yellow Poplar, White Ash, Blackberry, Black Cherry, and Crownbeard or any species listed as ozone-sensitive in this report: http://www.handsontheland.org/monitoring/projects/ozone/O3SensitiveSpp-on-NPS-FWS-Lands.pdf

- Show this slide show so students can learn to distinguish ozone leaf damage from other types of leaf damage: http://dnr.wi.gov/org/caer/ce/eek/earth/field/milkweed/slideshowindex.htm/ After watching the slide show, students should be able to identify at least three different characteristics of ozone leaf damage.

- Give students time to practice estimating percentages of foliar injury using this online training site until they can demonstrate 80% proficiency. Be sure students practice with the same species they will actually be monitoring: http://www.nature.nps.gov/air/edu/O3Training/index.cfm
- Additional monitoring practice: http://www.handsontheland.org/environmental-monitoring/ozone-bio-monitoring/ozone-inquiry.html

- Students should read this guide to become familiar with the ozone monitoring protocol of Hands on the Land: https://www.handsontheland.org/data/documents/ozone_monitoring_guide_2011.pdf

- Look for ozone injury during the mid to late summer. In the East, the best time to observe injury is between mid-July and mid-September. At higher elevations, however, ozone injury may be masked by early fall coloration.
- Find an opening with full sunlight exposure. Good places to look for ozone injury on bio-indicator plants are openings away from major paved roads and power lines such as clearings for wildlife, meadows, harvested areas.
- Select areas with no obvious conditions that would cause mimicking symptoms of ozone injury. Examples include herbicide applications and mechanical or physical damage. Determine the presence of herbicide or other damaging agent if many plant species in the area (in addition to bio-indicator plants) show the same symptoms.
- Look for symptoms on mature leaves that are in full sunlight. The leaves must be exposed to the sun to reveal injury.
- The typical symptom of ozone is an upper leaf surface stipple between veins. Stipple is the discoloration of small groups of cells between the veins, appearing as uniformly sized purple-red to brown spots.
- The ozone injury pattern normally does not go through to the underside of the leaf. If the injury pattern carries through to the underside, then the injury on the upper surface is probably caused by something other than ozone.
- Older leaves show injury. Look for injury on the more mature foliage in lower levels on the plant. There should be an increase in severity of injury from the youngest to the oldest leaves.
- Shaded portions of overlapped leaves do not show visible ozone injury.
- Some plants respond to ozone by dropping their injured leaves. Check on the ground beneath the plant to confirm if there is ozone injury on the fallen leaves.
- Signs of classic ozone injury:
    - Stipples (black dots), only found between the veins, not on them
    - Stipples are only found on the upper leaf surface
    - Stipples have distinct, sharp edges / No haloes or discoloration around the stipple
    - Black, purple or very dark dots; colors not variable
    - Stipple is scattered over the leaf surface -not clustered; more pronounced in older (lower) leaves

- Most leaves will have multiple types of damage caused by insects, diseases, nutrient problems or heat stress

- Report data on forms and upload to citizen science project database. Students should write about monitoring in their journals and glue data forms into journal after data has been uploaded.

2. Making and Using Schönbein strips as Ozone Indicators

Part I: Make the test strips

1. Makes 30-40 strips (each group should have 3 strips)
2. In a 250-ml beaker, combine 100 ml of distilled water and 1 ¼ teaspoons of cornstarch.
3. Heat and stir the mixture until you have a translucent gel.
4. Remove from heat and add ¼ teaspoon of potassium iodide; stir.
5. Cut the filter paper into one-inch-wide strips. Put tape on one end of the cut filter paper and punch a hole in the tape to make the hole for the string. Cut string into 2-foot lengths and attach to strips through the hole so that you have 2 loose ends to tie together.
6. When the solution is cool, use a paintbrush to brush it evenly onto both sides of each piece of filter paper.
7. If you are going to expose the test strips right away, skip the next two steps.
8. Let the paper dry out of direct sunlight. You may dry it in a low-temperature drying oven or in a microwave for about 30-45 seconds.
9. When dry, store the strips in a sealed plastic bag or glass jar out of direct sunlight.

Part II: Expose the test strips

1. If the test strips are dry, rewet them in distilled water using a spray bottle.
2. Hang them outside in various locations, but not in direct sunlight, for several hours until dry, then retrieve the strips. They should all be exposed for the same amount of time for accurate comparison. Eight hours is an ideal length of time, but you can collect sooner if necessary or leave them for 24 hours. If they will not be read right away when collected, seal them in plastic bags to stop the reaction.
3. When you hang the strips, use a psychrometer to determine the relative humidity of each location. If you don't have a psychrometer, look up the relative humidity for the testing day in a newspaper or on the Internet or use a real-time weather sensing app such as Weatherbug.
4. Place one unexposed strip in a sealed plastic bag as a control.

Part III: Interpret the test strips

1. Rewet the paper in distilled water.
2. Lavender and purple colors indicate the presence of ozone. If you expose the strips for a full day, the purple may fade to brown, as shown in the second color scale. The darker the color, the more ozone. Use the color scale to assign a Schönbein number to each strip.
3. Use the Relative Humidity Schönbein Number Chart to find the ozone concentration or level in parts per billion: Go up from the Schönbein number until you hit the appropriate relative humidity line, then read the ppb from the y-axis (see Student Page #2).
4. Compare results of the strips from different locations. Can you explain the differences?
5. Go to the website of the Division of Air Quality (www.ncair.org) and click on Air Quality Forecasts to find an official reading for ozone level for the day. Click on Today's Forecast to see current Ozone AQI levels. Click on Previously Observed to see the levels from the day before. Use the Ozone Air Quality Index chart to convert your results to the official reading. How does it compare to your results?
6. As a class, discuss your results. Do the results seem accurate? Any surprises? Did they support the hypothesis? What are some strategies the community could take to lower ozone levels or keep them low? Is this technique a good way to measure ground-level ozone pollution? Why or why not?
7. Be sure that students understand the chemical reaction involved with Schönbein strips.

Explain

Students should be able to explain the impact that air pollutants, and particularly ground-level ozone, have on organisms and on an ecosystem, and to argue from evidence whether the air is polluted by ozone.

Environmental Stewardship

- Students may research, design and plant an ozone garden using sensitive plant species, for ongoing monitoring of ground-level ozone.
- Students may research and create an indoor air filtering garden for the classroom. NASA Clean Air Study list of plants and the toxins they filter: http://en.wikipedia.org/wiki/NASA_Clean_Air_Study
- Students may choose and adopt activities that will reduce air pollution and its impact on plants and humans. Use the www.handprinter.org app to estimate the positive impact of selected activities.

Evaluate

- Review students' projects and presentations from the exploration stage.
- Review student observations, data, and discussions from the lab experiments.
- Evaluate contributions to garden projects and the citizen science projects.
- A rubric is provided for assessing student mastery of performance expectations.

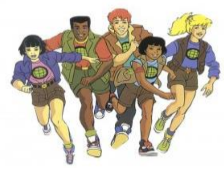
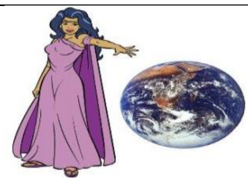
Extend

Give students the excess Schönbein strips to take home and expose outdoors near their homes. Compare the results the next day at school. Which parts of town appear to have the most and least ozone?

Air Chemistry in the Garden

Grade: *8* | ***Time:*** *(3-5) 50 minute periods*

Name: _ ***Date:*** _ ***School:*** _

Level of Mastery Benchmark or Performance Measure	 **EMERGING** **Not yet proficient** **1 point**	 **COMPETENT** **Partially proficient** **4 points**	 **PROFICIENT** **Mastered task** **5 points**	**TOTAL POINTS**
Particle Pollution Catcher	Made a pollution catcher and hung it.	Made a pollution catcher and counted some particles.	Made a particle pollution catcher, randomly selected and outlined 10 squares within a 100 sq cm section, counted particles in each square and averaged, looked up major pollutants in zip code, and wrote about findings in journal.	
Ozone Bio-monitoring Preparation and Proficiency	Watched EEK slideshow about identifying leaf damage due to ozone but cannot identify 3 types of evidence that point to ozone damage (such as black dots, on top of leaf, not in veins, no halos, etc). Practiced online estimating % of foliar damage on leaves of selected bio-monitoring species, but has not yet reached 80% proficiency.	Watched EEK slideshow and practiced estimating % foliar damage online. Can either identify 3 characteristics of ozone leaf damage or has reached at least 80% proficiency in estimating foliar damage, but not both.	Watched EEK slideshow and practiced estimating % foliar damage online. Can both identify 3 characteristics of ozone leaf damage and has reached at least 80% proficiency in estimating foliar damage.	
Ozone Bio-monitoring Citizen Science Project	Monitored plant for ozone damage but did not report data to citizen science database.	Monitored plant for ozone damage and reported data to citizen science project database that was partially complete or not in format.	Monitored plant for ozone damage and reported data to citizen science project database that was complete and in required format.	
Environmental Stewardship: Designing and Creating an Ozone Monitoring Garden or an Indoor Air Purifying Garden	Either contributed to design process or to installation of an ozone monitoring garden	Contributed to design process and helped install an ozone monitoring garden or indoor air purification garden	Contributed to design process, helped install it, and made the case for plant selection in journal	