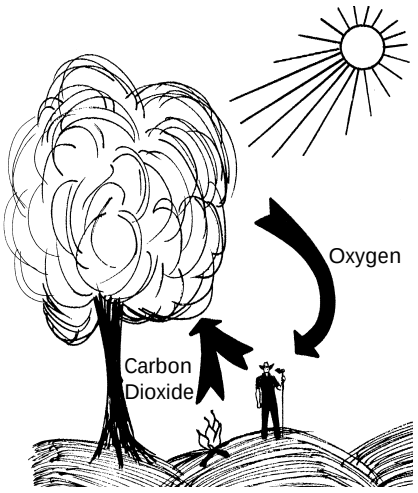
Virginia's Air Resources

Look up in the sky. Air seems boundless and, for that reason, it is a resource often taken for granted. Above the state of Virginia alone rests over one trillion tons of it. Yet even with all of this volume, air must constantly be reused. In fact, the air you are breathing now was in someone else's lungs earlier. Air is the ultimate recyclable material!

Q: Since oxygen is always being used to burn food into water and carbon dioxide, why doesn't it all get used up?
A: Photosynthesis. Green plants use light and carbon dioxide to produce glucose and oxygen. The use and reuse of oxygen is called the oxygen cycle.



The Oxygen Cycle

Air is a mixture of invisible and odorless gases, mostly oxygen and nitrogen. Water droplets, fine particles, and small amounts of other gases such as carbon dioxide, methane, ammonia, and argon are also part of the mix. If air is clean, we can neither see it, taste it, nor smell it.

What is Air Pollution?

Often what we can see or smell in the air is air pollution. Air pollution is any visible or invisible particle or gas found in the air that is not part of its normal composition. Some substances are so common and widespread, they build up in the air and become a hazard to human health.

The U.S. Environmental Protection Agency has developed health-based national air quality standards for six pollutants. They are: carbon monoxide, ozone, nitrogen dioxide, sulfur dioxide, particulate matter, and lead. In addition to these six criteria pollutants, standards have been set for over 120 toxic air pollutants (hazardous chemicals found in the air which are known or are suspected to cause cancer, genetic mutations, birth defects, or other serious illnesses in people even at low exposure levels). These contaminants include arsenic, benzene, beryllium, mercury, vinyl chloride, and radionuclides. Companies that produce such pollutants are required to use special equipment to control how much is emitted into the atmosphere.

Where Does Air Pollution Come From?

Air pollutants have occurred naturally since the earth's formation. Particulate matter and gases are emitted from every corner of the globe: from volcanoes, tree pollen, forest fires, and decaying organic matter in oceans and wetlands.

Air pollution, however, results from human activities — from burning coal, oil, wood, gasoline, and other fuels used to run factories, cars, farm and off-road vehicles, and construction equipment, and from power plants that generate heat and light for our homes and businesses. Burning these fuels produces smoke and gases (see chart on page 25.0). Smoke is made of tiny particles of soot and ash suspended in the air and called "particulate" matter. Sawdust from lumber mills, rock dust from quarries, and soil particles from bare earth are other examples of particulates found in the air.

Once particulates are added to the air, they can chemically react to form pollutants that are even more dangerous. For example, when nitrogen oxides interact with hydrocarbons in the presence of sunlight, ozone is formed. When it is formed at ground level, it acts as a powerful respiratory irritant that makes it hard for people to breathe. High levels of ozone, such as 0.12 parts per million, are frequently found in urban areas during hot summer months. When this happens, you are likely to hear an "air advisory" on the local radio or television station.

This is in sharp contrast to the ozone you may be most familiar with. That ozone, which exists in a layer found in the upper atmosphere (or stratosphere), provides a protective barrier against harmful radiation from the sun.

Just What is Ozone?
Ground-level ozone, the main ingredient of smog, is a colorless gas formed by the reaction of sunlight with vehicle emissions, gasoline fumes, solvent vapors, and power plant and industrial emissions. Ozone formation is most likely in hot, dry weather when the air is fairly still.

Ozone pollution is one of the most serious problems in Virginia's urban areas. Symptoms felt include shortness of breath, chest pain when inhaling deeply, wheezing, and coughing. Children, people with respiratory disease, and individuals who exercise outdoors are at particular risk from high ozone levels.

Always On the Move
Pollutants of any sort can ride the air currents for long distances. Much of Virginia's pollution is carried in from sources in the Midwest, especially large coal-fired power plants. Air can usually "cleanse" itself by such processes as rain; otherwise dense, poisonous clouds would already cover the earth. Sometimes the weather does not permit this cleansing to happen, and the air stagnates due to a weather condition known as an inversion.

Normally, as you go higher up in the air, the temperature gets colder. Hot polluted gas from cars or smokestacks rises through the cooler air above and blows away. Sometimes a layer of warm air forms above the cooler air below (often in a valley like Roanoke or Charlottesville). When this inversion happens, the polluted air will rise up to the warm layer and then stop. In this way, a giant cloud of pollution can form over a community.

While the air may be cleansed after a good rain, many of the chemicals and small particles washed from the atmosphere become land or water pollution. In fact, scientists have estimated that as much as 25-30 percent of the nitrogen pollution in the Chesapeake Bay is a result of acid deposition. While "normal" rainfall has a pH of about 5.5, precipitation in Virginia can be up to ten times more acidic, ranging from 4.3 to 4.5.

What Are the Effects of Air Pollution?
Air pollution is dirty and it is expensive. More important, polluted air can make healthy people cough and wheeze. For people who are sick or especially sensitive, air pollution may worsen an existing condition and mean discomfort, limited activities, increased use of medication, and more visits to doctors and hospitals. A growing body of scientific studies suggests that air pollution has long-term effects on the lung's ability to function and contributes to the development of lung disease.

Our noses and sinuses have a built-in filtration system that traps large dust particles before they get into our lungs. And human lungs have a natural defense system that helps to protect us against some of the air pollutants breathed. But people respond differently to air pollution. How people respond, or their level of risk, depends on several factors, including the amount of pollution in the air, the amount of air breathed in a given time, and their age and overall health.

INNOVATIONS AT THE MT. STORM POWER STATION

Virginia Power is getting into the pollution prevention act by using smokestack scrubbers to help reduce acid rain. At the Mt. Storm Power Station in West Virginia, smokestacks will be fitted with scrubbers that are expected to remove 95% of the sulfur dioxide from the smoke created by burning coal. (Sulfur oxides can mix with moisture in the air and become a component of acid rain.)

The process works through a chemical reaction called neutralization when calcium in limestone, a base, mixes with sulfur dioxide, an acidic gas in the smoke, and creates calcium sulfate or gypsum. Some of the gypsum will be used to reclaim acidic water at mines near the plant. Virginia Power expects each of the scrubbers to remove about 55,000 tons of sulfur dioxide a year. This pollution prevention method is not only cost-effective for the power company, but also benefits air quality east of the plant (including the Shenandoah National Park).

Just What is Acid Rain?

"Acid rain" is really rain, snow, or fog that contains sulfuric or nitric acid. Acid rain, or "deposition," forms when water vapor mixes with sulfur and nitrogen oxides. Sulfur and nitrogen come from natural sources like volcanoes, but are common by-products of the combustion of fossil fuels (coal and petroleum), which are burned principally to heat homes and generate electrical power. Sulfur dioxide and nitrogen oxides released during burning usually travel many miles before falling to the ground as acid rain.

Acid is a measure on a pH scale ranging from 0, which is severely acidic, to 14, which is extremely alkaline, or basic. A value of 7 is neutral. Lemon juice has a pH of 2; baking soda, 8; a cola drink, 4; and pristine rain is about 5.6. Natural precipitation is about ten times less acidic than the average value of rainfall in Virginia — 4.3 (extremely acid). However, pH can vary from week to week (and rainstorm to rainstorm) from 3.5 to 5.0. Acid deposition levels in Virginia are comparable to other areas of the mid-Atlantic and Northeast regions of the U.S.

Effects of Acid Rain

Sulfuric acid in the air can hurt the lungs of infants, children, and adults. It can contaminate drinking water by dissolving minerals from soil and pipes which are then carried into the water supply. Acid rain has been blamed for damaging mountain streams in Virginia and the northeastern United States. High acidity levels can kill new fish eggs. Airborne nitrogen oxide is also believed to be responsible for an estimated 30 percent of the nitrogen pollution entering the Chesapeake Bay. Excessive nitrogen and other nutrients in the Bay overstimulate algae growth, thereby reducing the oxygen levels available for other plants and fish.

Scientific studies performed in the early '90s confirm that initial estimates of the national damage caused by acid rain were overstated. However, central Appalachian region ecosystems are severely stressed by acid deposition due to the low neutralizing capacity of local soils. The physical and chemical properties of these soils are such that they cannot buffer, or offset, the acid. This region of the state unfortunately receives a high rate of deposition, especially sulfur compounds from power plants in the Midwest.

What Can Be Done?

Managing air is a complex undertaking because it is a substance constantly on the move. Air is affected by sunlight, dust particles, water vapor, and wind currents—factors which by their very nature are also moving.

When it comes to air pollution, technology has served as both a culprit and a cure. Devices used to control pollution from smokestacks and exhaust vents include:

1) The *cyclone* — a system where heavy dust is spun right out of the air.

2) The *electrostatic precipitator* — which uses static electricity to attract dust particles, in the same way that a comb picks up bits of paper after being charged with static electricity by your hair.

3) The *scrubber* — which uses a water spray to wash dust and gases from the air.

4) The *filter system/bag house* — which works like a vacuum cleaner bag to collect dust.

Some emissions are pre-treated before being released. For example, some power plants spray a limestone slurry (a mixture of limestone and water) to neutralize the acid resulting from burning coal. Catalytic converters that help decrease emissions from automobiles are another example.

Of all the types of pollution, odors are probably the hardest to control because we can smell even tiny amounts of so many substances. (The nose is a great piece of monitoring equipment!) A new technology called biofilters actually uses bacteria to "eat" odors.

What Are Those in Government Doing About Air Pollution?

The U.S. Congress passed important federal air pollution laws, known collectively as the Clean Air Act (1963; and amended in 1967, 1970, 1977, and 1990). National air quality standards spelled out how clean the outdoor air has to be, and it is up to each state to see that its air meets these standards.

In 1966, the Virginia General Assembly passed the Virginia Air Pollution Control Law. The regulations are administered and enforced by the Department of Environmental Quality.

Some of the goals of the new Clean Air Act Amendments are listed here:

u Reduce hazardous pollutant emissions within 10 years.

u Decrease urban smog by reducing emissions from small businesses as well as large factories and vehicles.

u Reduce emissions from electric utilities in two stages by the year 2000: ten million tons of sulfur dioxide, and two million tons of nitrogen oxide.

u Both new and existing sources of toxic pollutants that are identified as subject to Maximum Achievable Control Technology (MACT) will be expected to reduce emissions by 90% or more.

In Virginia, the Department of Environmental Quality and the Department of Health work closely with the U.S. Environmental Protection Agency to monitor and evaluate hazardous air pollutants across the state. A newly developed computer model that estimates concentrations of 148 hazardous air pollutants statewide helps the state pinpoint regions of most concern. Data from 1996 is currently being added to the model and will allow close evaluation of the state's air pollution strategies since 1990.

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Virginia is working to achieve the requirements of the 1990 Clean Air Act, a federal law amended by Congress. One provision, Title IV, calls for reductions of sulfur dioxide of approximately ten million tons per year and two million tons of nitrogen oxides per year. Virginia's power plants already meet the standard for sulfur dioxide and are preparing to take whatever steps are necessary to meet the nitrogen oxide standard. Most of the reductions in pollutants will occur at large coal-fired power plants in the Midwest. Some of these individual plants emit more than all the sources in Virginia combined. Emissions from these large plants are released from very tall smokestacks and travel eastward, sometimes hundreds of miles, before returning to Earth in precipitation or dust.

Prevention is Key

Like so many other forms of pollution, the surest solution to air pollution is prevention. This means many things. It means wise transportation and community planning. It means adopting new processes and materials for industrial operators. It means each person doing their share by conserving the resources they use, particularly electricity and gasoline.

Additional Resources

Web Sites:

u Va. Department of Environmental Quality; www.deq.state.va.us

u National Oceanic and Atmospheric Administration; www.nnic.noaa.gov/CENR/NAPAP/NAPAP_96.htm, or www.oar.noaa.gov/NAPAP/

u Wolverton Environmental Services, 514 Pine Grove Rd., Picayune, MS 39466; www.Wolvertonenvironmetnal.com

u U.S. Environmental Protection Agency, Office of Air and Radiation; www.epa.gov/oar/

Other Resources:

u To learn more about acid deposition, contact the National Acid Precipitation Program at (301) 713-2465 and ask for a copy of their latest report, or visit these web sites (listed above).

u The Plants for Clean Air Council, 10210 Bald Hill Rd., Mitchellville, MD 20721.

u Air and Waste Management Association, One Gateway Center, 3rd Floor, Pittsburgh, PA 15222, (412) 232-3444.

Fundamental Learnings Related to Air

R Air is one of the physical or abiotic (nonliving) factors that influence living organisms.

R There are two main types of air pollutants: primary and secondary. Primary pollutants are those emitted directly into the air, such as smoke and chemicals (particulates, oxides of nitrogen hydrocarbons, sulfur dioxide, and carbon monoxide). Secondary pollutants are produced from the chemical interactions of primary pollutants with other atmospheric compounds. Examples are smog, acid rain, and ozone.

R Particulates are small particles such as dust or soot that contribute to air pollution. Natural processes such as forest fires and volcanic eruptions, as well as man-made processes such as burning coal or oil (fossil fuel), release air pollutants.

R Burning fossil fuels emits chemical by-products. These combine with moisture in the atmosphere to form acids, which fall as acid precipitation (rain or snow).

R Air pollution affects the health of lakes, forests, wildlife, crops, water supplies, and humans.

Indoor Air Pollution Solutions

Background

Discuss with your students the concept of air pollution and its various forms. We have all seen air pollution—smoke that comes out of the exhaust pipe of buses, trucks, and cars. What about the air inside your home or school? Is this air "safe" to breathe? Is it clean?

Discuss the idea that while your indoor air may look and smell clean because you can't see any pollution, scientists have found that the air inside your house and school contains an invisible and often odorless form of gaseous chemicals emitted from many everyday furnishings and objects. In particular, poorly ventilated buildings trap these gases and are more prone to indoor air pollution, because the air cannot circulate and is not replenished with cleaner air.

Discuss indoor air pollution, including tobacco smoke, dust, paint thinner, cleaners, pesticides, radon gas, wood burning fireplaces, chemicals from personal care products, and so on. Explain that gases can be odorless and invisible and that high concentrations can be harmful.

The chemicals in the air are emitted from everyday objects that you would find and use around your home and in your school. Things that you would never expect to contribute to air pollution include: the furniture in your house or school, the paint on the walls, carpeting, the ink in printed materials such as books and newspapers, plastic and painted toys, and dry-cleaning solutions used to clean your clothes.

Explain to students that the chemicals used in or resulting from the manufacturing process of these products are emitted into the air and can cause your eyes, nose, and throat to feel irritated. These chemicals may cause headaches, make you feel drowsy, or develop more severe symptoms. In these cases, where the air inside buildings has made people feel sick, scientists have come up with the name "sick building syndrome" to describe the problem. The strength of the pollutant in the air, the amount of air in the room, how much air is being used up (breathed in), as well as the sensitivity of each individual plays a role in this process. Often, scientific equipment is used to measure the presence and amounts of substances in the air.

Share with students that there are some simple things that they can do to help clean the air. NASA researchers, led by Bill Wolverton, Ph.D., have found that common house plants can rid the air of a variety of pollutants. In particular, findings from his research are used to remove airborne pollutants from sealed environments like the space station.

Discuss photosynthesis, the process by which plants clean the air. It works like this: plants absorb carbon dioxide, which we exhale, and give off oxygen, which we breathe in. Plants absorb the pollutants/gasses through their leaves and roots and convert them to harmless substances. Scientists have found that in laboratory studies plants removed as much as 87% of the indoor air pollution within 24 hours!

Grade Levels:
Activity 1 - 5th grade
Activity 2 - 5th & 6th grades

Science SOLs:
5.4, 5.6, 6.9, 6.10

Materials:
- **Calculator**
- **Tape measure (if using classroom as the setting)**

Objectives:
1. **Students will understand air pollutants, including invisible and non-odorous sources of indoor air pollution.**
2. **Students will understand the link between breathing polluted indoor air and health.**
3. **Students will develop solutions to this pollution in a "real-life" setting.**

Vocabulary Words:
emission
microgram
sick building syndrome

Table 1: List of common pollutants, side effects, sources, and pollution-fighting plants.

Pollutant	Possible Side Effect	Source	Pollution Fighter
Benzene	skin and eye irritant, headaches, loss of appetite, drowsiness, tiredness, and other	inks, oils, paints, plastics, rubber, dye, detergents, gasoline, tobacco smoke, synthetic fibers	Dracaena marginata, English ivy, Janet Craig (fern), Warneckel, Peace lily
Formaldehyde	irritated eyes, nose, throat, headaches, contact dermatitis, and others	foam insulation, plywood, particle board, pressed wood products, plastic grocery bags, wax paper, facial tissue, paper towels, water repellants, adhesive binders in floor coverings, cigarette smoke, natural gas and kerosene, new synthetic carpets, new furniture made from pressed wood	Boston fern, Chrysanthemum, Gerber daisy, Dwarf date palm, Bamboo palm
Thrichloro-ethylene	potential for liver damage	used in dry cleaning and in printing inks, paints, varnish, and adhesives	Gerber daisy, Peace lily, Warneckel, Chrysanthemum, Dracaena marginata
Xylene		a solvent in paints and varnishes	Areca palm, Chrysalidocarpus, Lutescens, Dwarf date palm, Phoenix roebelenii, Bamboo palm, and others

Dr. Bill Wolverton, who currently maintains his own laboratory facility, has worked both at NASA and as a consultant to *The Plants for Clean Air Council*. Through his research he developed a formula that you can use to create a plan for clean air in your classroom or home:

> **Two or three plants per 10 square meters* (or 22.6 cubic meters with a standard ceiling). If you have a newly constructed house or lots of new furniture, you should fill each room with plants.**
>
> ***hundred square feet of space for a standard building**

Activity #1: 5th grade level

Read the following scenario to your students:

The school you attend is 10 years old. It is the fall and late last spring new carpeting was installed. In addition, during the past summer, all the halls in your school were repainted. Your classroom received a large workstation (3m x 2m) comprised primarily of pressed wood.

- Have students measure your classroom to determine its square footage.
- Determine the number of plants needed to keep the air clean.
- Determine the types of plants needed to clean the air based on materials contained in the room.

Activity #2 5th and 6th grades

Dr. Wolverton's research has found that different plants remove chemicals from the air at varying rates. In other words, the volume of "air exchange" that one plant can treat varies by the type of plant and chemical being treated for. In addition, the U.S. Environmental Protection Agency (EPA) has conducted research to determine the mean indoor air concentration of chemicals found in various buildings.

Table 2: Removal Rate Per Hour by Plant Type

Plant Type	Removal Rate Per Hour: Formaldehyde	Xylene
Boston Fern	1863 µg/hour	208 µg/hour
Janet Craig	1361 µg/hour	154 µg/hour
Rhododendron	617 µg/hour	168 µg/hour

µg=microgram (one-thousandth of a gram)

Table 3: Mean Indoor Air Concentration of Chemicals Found in Nursing Homes

Chemical	Mean Concentration
Formaldehyde	0.081 µg/liter
Xylene	0.005 µg/liter

Use the following as a case study to determine which and how many plants are needed to clean the air continuously:

u You have been brought in to consult with the managers of a local nursing home facility. Residents have complained recently of headaches and tired, scratchy, irritated eyes. The facility is 25 years old and has undergone recent renovation including new paint throughout and new carpeting in each resident's room. Each resident has also received new furnishings made of pressed wood board, including a bed and bedside table for their individual room. The room measurements are 3.05 meters long by 3.05 meters wide, with a 2.4-meter ceiling.

u The managers of this facility are asking for your help to reduce the number of complaints they are receiving from the residents and make them more comfortable in their surroundings.

1. Determine the origins of the chemicals that may be causing the residents' symptoms.

2. Determine which types of plants would be best used to clean the air of the specific chemicals involved.

3. Use the steps below to determine how many plants are needed to clean the air in each nursing home room:

u Calculate the air volume in the room by entering the dimensions of the room into the formula below:

length_____ x width_____ x height _____ = cubic meters
***Answer**: 22.64 cubic meters*

u Calculate the average concentration (amount) of each pollutant in the room by using the data in Table #3.

22.64 cubic meters x 1000 liters x _____mean (concentration) μg = _____ μg
***Answer**: 22,640 liters x .081 micrograms per liter (formaldehyde)=1834 μg*
22,640 x .005 micrograms per liter (xylene) = 113 μg

u Refer to Table #2 for the removal rates of plants to determine the number of each type of plant needed to clean the air.

_____μg pollutant divided by the removal rate/hour = number of plants needed to clean the air
***Answer**: 1834 divided by 1863 (Boston fern) = 1 Boston fern plant.*
You can use the same formula for other plants types as well.

Use the table below to collect your responses:

Chemical	Amount of Chemical (found in each room)	Plant Type	Number of Plants Required

Answers:

Chemical	Amount of Chemical	Plant Type	Number of Plants
Formaldehyde	1834 μg	Boston Fern	1
		Janet Craig	2
		Rhododendron	3
Xylene	113 μg	Boston Fern	1
		Janet Craig	1
		Rhododendron	1

Extension: Complete the above activity(ies) using the dimensions of your own classroom and any applicable environmental conditions.

Major Man-made Air Pollutants

Pollutant	Description	Sources	Effects
Carbon monoxide (CO)	colorless, odorless gas	t vehicles burning gasoline t indoor sources include kerosene- or wood-burning stoves	t headaches, reduced mental alertness, heart damage, death
Lead (Pb)	metallic element	t vehicles burning leaded gasoline t metal refineries	t brain and kidney damage t contaminated crops and livestock
Nitrogen oxides (NO_x)	several gaseous compounds made up of nitrogen and oxygen	t vehicles t power plants burning fossil fuels t coal-burning stoves	t lung damage t react in atmosphere to form acid rain t deteriorate buildings and statues t damage forests t form ozone and other pollutants (smog)
Ozone (O_3)	gaseous pollutant	t vehicle exhaust and certain other fumes t formed from other air pollutants in the presence of sunlight	t lung damage t eye irritation t respiratory tract problems t damages vegetation t smog
Particulate matter	very small particles of soot, dust, or other matter, including tiny droplets of liquids	t diesel engines t power plants t industries t windblown dust t wood stoves	t lung damage t eye irritation t damages crops t reduces visibility t discolors buildings and statues
Sulfur dioxide (SO_2)	gaseous compound made up of sulfur and oxygen	t coal-burning power plants and industries t coal-burning stoves t refineries	t eye irritation t lung damage t kills aquatic life t reacts in atmosphere to form acid rain t damages forests t deteriorates buildings and statues

OZONE "BUSTERS"

Virginians can help reduce ozone on summer days in a number of ways:

- Avoid unnecessary car trips. Use the telephone or fax machine whenever possible. If you must drive, combine errands.
- Carpool, vanpool, or use public transportation (buses, subways, trains) when possible.
- Drive the most fuel-efficient vehicle available.
- Keep your car engine properly tuned and tires properly inflated.
- Avoid excessive engine idling while driving. Idling for more than 30-40 seconds uses more gasoline than restarting the engine.
- Refuel vehicles after dusk or early in the morning.
- Limit lawn mowing and the use of other gasoline-powered equipment, including outboard motors.
- Limit or halt open burning.
- Turn off unnecessary lights and electric appliances. If possible, raise the thermostat setting by 2-4 degrees to use less air conditioning. The less energy used, the less must be generated by power plants.