

5600 How Clean Is The Air

The objective of this demonstration kit is to supplement student study of the basic concepts of air pollution. The instructions and materials provided in this kit are ideal for: a class demonstration, or a student/student group study. The following activities may be done:

Collect dust particles in the open air over a seven day period and visually examine them.

Test for air pollution by exposing nylon mesh to the open air over a four week period.

Test air for nitrogen oxides by exposing special test fabric over a 30 day period.

Test engine exhaust for nitrogen oxides using special test fabric over a one week period.

Demonstrate acid rain formation.

Demonstrate the acidity of smoke.

Test local air for the presence of acid forming gases.

Demonstrate the impact of acid rain on a common building stone.

Contents:

Labels (6)	Limestone (5 pieces)
Magnifying Glass (1)	Nitrogen Oxide Test Fabric (5 x 7 cm piece)
Metal Cups (3 – 60 ml)	Nylon Mesh (1 piece)
Pipet (1)	pH Test Strip (2 strips)
Plastic Syringe (1)	Bromothymol Blue (30 ml bottle)
Plastic Cup (1 – 30 ml)	Bromothymol Blue
Rubber Bands (2)	Ethyl Alcohol
Straws (2)	Distilled Water
Smoke Density Comparator	Vinegar (30 ml bottle)
Sawdust (1 bag)	Teacher/Student Manual (1)
Test Tube (1)	
Tubing (1 piece)	

Additional Materials Required:

Cardboard	Ruler
Distilled Water	Scissors
Matches	Scotch or Masking Tape
New Fabric Samples	Test Tube Rack

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Teacher/Student Instructions

Background:

The atmosphere protects and supports all life on earth. Without it, Earth would be a “dead” planet. Clean dry air is a mixture of many gases. The major components, nitrogen (78.08%), oxygen (20.95%), argon (0.934%) and carbon dioxide (0.035%) comprise 99.99% of the air. Clean air also contains varying amounts of water vapor and trace amounts of neon, helium, methane, krypton, hydrogen, carbon monoxide, xenon, ozone, ammonia, nitrogen oxides, sulfur oxides and hydrogen sulfide. When there is an imbalance in the ratio of normal air gases, for example, increased sulfur dioxide, or the introduction of a substance not found in clean air, the air becomes polluted.

An air pollutant is any substance which changes the physical or chemical properties of clean air and causes measurable effects on humans, animals, vegetation or materials.

Air pollution is not a simple subject. The atmosphere provides the medium for the continuous interplay complex chemical reactions. Natural events and anthropogenic (related to mankind) activities contribute significantly to the complexity and effects of these chemical reactions. For our discussion we will broadly classify air pollutants as either particulates or gases.

Particulate Air Pollution

Particulates or aerosols, the most visible form of air pollution, are small particles of solid matter and liquid droplets suspended in the air. Thousands of tons of particulate matter are introduced into the air every day in the form of mists, smoke, fumes and dusts. Many components of these aerosols are harmful to living things in high concentration. Large quantities of smoke and/or dust are generated by coal and oil burning power plants, petroleum refineries, steel manufacturing, and agricultural burning. Smoke and fumes are also released by natural events like forest fires and volcanoes, but these sources are usually spread apart in both distance and time. Man's activities are a more serious source of pollution because they are concentrated and steady.

The two main sources of anthropogenic pollution are industrial processes and combustion of fuels, particularly coal. Wood, plastic, paper, cement, mineral and grain processing operations, all release significant quantities of particulate into the air. In addition, over cultivation of agricultural areas leads to a loss of vegetation, followed by wind erosion of the soil and creation of dusts.

Particulates pose a number of problems. First, and most obvious, particulates reduce visibility. Second, solid particles interfere with transpiration of plants by coating their leaves and making gas transfer more difficult. Man and animals are susceptible to very small particles and mists which can be breathed in and caught in the respiratory tract. Well documented examples include lung cancer from asbestos particles and cigarette smoke, and black lung disease and emphysema from coal dust. Particulates also provide a surface for atmospheric chemical reactions resulting in conditions like smog. Finally, atmospheric water vapor condenses on particulates and effects the weather.

Gaseous Air Pollution

Particulate pollution may be the most visible, but particulates are only a part of the equation. The gases carbon monoxide, nitrogen oxides, sulfur oxides, and the hydrocarbons are pumped into the atmosphere by high temperature industrial processes and the internal combustion engine. They can cause extensive damage to living things, property, clothing, and buildings. These pollutants can act directly as gases, or indirectly, dissolved in water or as contributors to chemical reactions forming other polluting products.

Carbon monoxide is extremely toxic to man and animals. Nature adds it to the air with the decay of plant matter. Internal combustion engines are the primary localized source of this gas.

Naturally added sulfur oxides come from volcanoes. The number one anthropogenic source is the burning of fossil fuels, oil and coal. These oxides along with nitrogen oxides react with atmospheric water forming particulates and are subsequently removed from the air as acid rain. They also react with metal salts and ammonia to cause respiratory tract irritation. Plant leaf tissue dies with exposure to sulfur dioxide.

A small amount of the nitrogen oxides are produced by lightning and bio processes. The major contributor is combustion of fossil fuels. In the atmosphere, nitrogen oxides are converted to nitric acid, nitrate salts and organic nitrates. Nitrogen dioxide is extremely toxic to man, animals and plants. It is also known to fade certain dyes and inks.

National air quality standards and state laws have caused industry to introduce air pollution abatement measures. Our cars burn cleaner and industry is taking more responsibility to control their polluting by products. The air however, covers the earth and until all nations accept their responsibility to maintain clean air, mankind will still be the major contributor to air pollution.

Using the Kit:

Carefully read the teacher/Student Manual & Instructions and the Safety Instructions. When used properly, the materials in this kit are safe.

Suggested Readings and Activities:

- Contact the United States Environmental Protection Agency or your State environmental department for information on national and regional air quality.
- Contact your State or local environmental agency for a tour of testing and monitoring facilities.
- Check the Internet or on line services for information on air quality.
- Write to your congressman to find out what legislation dealing with air quality in your area is under consideration. Find out the background of the bill and what hearings have been or will be held.
- Contact local manufacturing plants. Many of them are willing to provide information or tours related to their environmental quality control measures.
- Environmental Chemistry, 6th Ed. Stanley E. Manahan, CRC Press, Inc: Boca Raton, Fl., 1994. The primer for environmental chemistry studies.

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Teacher/Student Instructions

Dust Particle Monitoring

Some airborne particles are large enough to be seen with the naked eye or under low power magnification. These dust particles are transported by the wind, and are also affected by gravity. You will collect these windblown particles with the following experimental procedures:

Materials:

Adhesive Labels	Ruler	Shipping Container from the Kit
Magnifying Glass	Scissors	

Testing Procedure:

- Cut off the top of the shipping box or get another box.
- With the sticky side of the label facing out, tape one label on each side of the box. Tape one label on the inside floor of the box.



- Tape a label on the ceiling of a closet, the underside of a shelf, or the ceiling of your room.
- Place the box in a location that is exposed to the open air, sheltered from rain and at least three feet off the ground. Leave it there for 7 days.
- Carefully remove all the labels and tape onto a piece of paper. Next to each label, describe where it was located on the box and the orientation of the box. (For example: front of box, facing south, parking lot or left side, facing east, four foot from school building.)
- Look at the six labels and record any differences. Take a closer look with the magnifying glass.

Do you see any differences among the appearance of the six labels?

Do the four sides of the box receive equal amounts of particles?

Where are most of the large particles and why?

Do you find any evidence of materials from plants or animals, or of material that appears man-made?

- Draw three - one centimeter squares on the label from the floor of the box. Using the magnifying glass, count the particles within each of the three squares. If there are too many to count, estimate. An average count of the three boxes is your value. Counts over 500 per square centimeter indicate high particle pollution, between 100 to 500, mild particle pollution.

Deterioration of Nylon

Harmful chemicals are introduced into the atmosphere by smoke and dusts. You will check the general level of airborne pollutants in your area with this procedure

Materials:

Magnifying glass
Metal Cups (2)

Rubber Bands
Scissors

Nylon Mesh

Testing Procedure:

- Cut 2 pieces of nylon mesh to fit the metal cups. Stretch one piece over each cup and secure with the rubber bands.
- Examine both samples for breaks and runs, and record any you find.
- Place one cup outdoors in a location exposed to the air, but sheltered from the rain. Place the other cup in a closed cabinet. Be sure that both cups are away from direct heat. Do not disturb the cups for 4 weeks.
- After exposing the nylon samples for this extended period of time, examine both of them with the magnifying lens.
- If the two pieces of nylon have about the same number (close to zero) of breaks in the mesh, the local air is relatively unpolluted.
- If the sample from the open air has more than 5 new breaks in it, then the air in your region probably has a significant level of acid forming chemicals.

Smoke Monitoring

The particles of smoke are quite small. Individually, they can't be seen with the unaided eye. Methods are available to measure the amount of smoke particles emitted into the air. Current tests use a spectrophotometer or smoke meter which pass light across the area with the greatest opacity of the smoke plume (US EPA Method 9, 1990). This principle of measuring the opacity of stationary source emissions, however, has been used for many years. In the early 1960's a test was designed to measure the amount of particles emitted from factory smokestacks based on percentage of air opacity. The following experiment uses a smoke comparator to measure the density of a smokestack's plume or chimney.

Materials Required:

Smoke Density Comparator

Source of Smoke...factory smokestack, chimney

Testing Procedure:

Select a site to be tested. Stand at least 100 feet but not more than 1/4 mile from the smokestack or chimney with the sun at your back. Look through the hole in the comparator at the smoke as it emerges from the top of the smokestack. Hold the comparator at arm's length. Then, compare the grey segments on the comparator with the view through the hole. The corresponding percentage is the percent opacity. A reading of 20% or less is considered generally acceptable and most smokestacks fit into this category. A higher percent opacity is representative of some pollution. Can you find different readings between chimneys and factory smokestacks? Do you find weather (wind direction, wind speed, ambient temperature) to be a variable in the percent opacity reading?

Fabric Fading Due to Nitrogen Oxides

The stability of colors in dyed fabrics is extremely variable. Strong sunlight, washing, heat and humidity are all responsible for color fading. Air pollution in the form of nitrogen oxides, will also cause of fabric to fade. The major source of nitrogen oxides is gasoline and diesel engine exhaust fumes.

In the next procedure, a strip of special dyed fabric that is sensitive to nitrogen oxides will be exposed to the air for an extended time. The fading of this special fabric will provide a rough measure of the concentration of nitrogen oxides in the air.

At the same time, you will also expose a piece of new dyed fabric from home. This will provide a rough measure of the fading you may be experiencing as a result of air pollution.

Materials:

Cardboard
Nitrogen Oxides Sensitive Fabric
Plain Dyed Fabric, preferably new

Testing Procedure:

- Cut the nitrogen oxide sensitive fabric into three pieces.
- Staple one piece of nitrogen sensitive fabric and a piece of new fabric to the of cardboard.
- Place the samples outside, out of direct sunlight, for thirty days.
- Tape one piece of the sensitive fabric and a piece of new fabric to the underside of a car bumper, near the exhaust pipe. Leave on the car for one week or at least 100 miles.
- As a control, keep a piece of each fabric in an air tight container. This is so you can compare your test samples with the original samples.
- Observe the fabrics each day and note any obvious deterioration, such as a strand snapping, color fading, etc.
- The degree of fading of the samples as compared to the control samples, will give sense of the amount of nitrogen oxides present in the atmosphere or verify that cars exhaust nitrogen oxides.

Pollutants Dissolved in Rain Water

A variety of chemicals in the air dissolve in rain water as it is falling. Some of these chemicals cause the rain to become very acidic. Acids are corrosive to metals and attack minerals.

There are two major types of gas that cause rain water to become more acidic.: nitrogen oxides and sulfur oxides. They are produced by high temperature industrial processes and internal combustion engines.

Materials:

Cardboard	Plastic Cup	Limestone
Matches	pH Indicator Strip	Bromothymol Blue Solution
Metal Cup	Straw	Vinegar
Pipet	Tubing	

Demonstration Procedure 1:

- Pipet 3 ml of water into the test tube.
- Add Bromothymol blue solution to the water until it noticeably turns color (3 to 5 drops)

Acidity is measured in terms of pH (the negative logarithm of the hydrogen ion concentration) A pH of 7 is neutral. pH values above 7 are alkaline, below 7 are acidic. Bromothymol blue is a pH indicator and changes color in the pH range of 6 (yellow) to 7.6 (blue).

Based on the color of the indicator, what can you say about the pH of the tap water in your area?

Note: If the water in the test tube is yellow, use distilled water I for the next step.

- If the water in the tube is green or blue, use the straw to gently blow air through the water. Be careful not to suck up the indicator with the straw. It is poisonous! Keep blowing until you notice a change in color. Carbon dioxide in your breath will cause the solution to become acidic.
- Empty the test tube and rinse with distilled water.

All animals produce carbon dioxide. This carbon dioxide, however, is normally used up by plants during the process of photosynthesis. Pollution occurs, when large amounts of carbon dioxide and other similar compounds are introduced into the air.

Demonstration Procedure 2:

- Take a pH indicator strip and using distilled water, wet the sensitive area in the middle of the strip.
- Place a small amount of torn paper and sawdust in one of the metal cups, light it, and allow the wood to burn for a few seconds, then blow it out.
- Hold the pH indicator strip in the smoke. Note any color change.

What happens to the color of the pH indicator strip?

What can you say about the effect of smoke components on the pH of atmospheric water?

Testing Procedure:

- Add 10 ml of distilled water and 5 drops of Bromothymol blue indicator. This time, you will test the local air.
- Attach the tubing to the end of the syringe. Fill the clean syringe with outside air. Gently blow the air through the water, then refill the syringe with air, and repeat at least 10 times. Note any color change.
- If the solution remains green, then the air in your region has fairly low concentrations of acidic gases.
- A color change to yellow indicates a high concentration of acid producing gases, and a potential health and property hazard.
- Rinse the tube and syringe with distilled water.

When acid forming gases dissolve in water, they produce a solution which has the ability to corrode many metals, minerals and rocks as well as damage vegetation and affect the pH of water bodies. This corrosion process may appear slow when examined directly, but can produce extensive damage in the course of only a few years.

We can simulate the process more rapidly by using a solution that is more acidic than most acidified rain waters.

Demonstration Procedure 3:

- Place a piece of limestone (calcium carbonate) in the plastic cup. Limestone is a mineral similar to marble. Both are common building stones.
- Pipet, a 5 - 7 drops of tap water onto the limestone.

What happens to the rock?

- Add 5 drops of vinegar to simulate the effect of acidified rain.

What happens to the rock now?

What does this tell you about the extensive decay of the statues and buildings in areas that have developed a great deal of industry?

(Vinegar will break down the limestone and produce bubbles of carbon dioxide. Acid rain in many areas has caused a great deal of damage to marble and limestone statues and buildings.)

In certain parts of the U.S. acid rain has damaged vegetation and acidified lakes and ponds to such a degree that they did not support marine life. This acid rain is produced from sulfur oxides being converted to sulfuric acid. The sulfur oxides are produced in the burning of high sulfur content coal used as fuel for electrical generating stations.

What other types of fuel could be used for electrical generation that would not use high sulfur content coal that produce sulfur oxides?