# Pollution Patrol



## Lesson Focus

This lesson focuses on devices that are used to detect air pollution. Teams of students construct outdoor air pollution detectors from everyday materials. They then test their devices to see how much particulate pollutants they can capture.

## Lesson Synopsis

The "Pollution Patrol" lesson explores how engineers design devices that can detect the presence of pollutants in the air. Students work in teams of "engineers" to design and build their own outdoor air pollution detectors out of everyday items. They then test their air pollution detectors, evaluate their results, and present to the class.

## Age Levels

8-18.

## Objectives

Students will:

- Design and build an outdoor air pollution detector
- Test and refine their designs
- Communicate their design process and results

## Anticipated Learner Outcomes

As a result of this lesson students will have:

- Designed and built an outdoor air pollution detector
- Tested and refined their designs
- Communicated their design process and results

## Lesson Activities

In this lesson, students work in teams of "engineers" to design and build their own outdoor air pollution detectors out of everyday items. They then test their devices, evaluate their results, and present to the class.

## Resources/Materials

- Teacher Resource Documents (attached)
- Student Worksheets (attached)
- Student Resource Sheets (attached)

## Alignment to Curriculum Frameworks

See attached curriculum alignment sheet.

## Internet Connections

- TryEngineering (www.tryengineering.org)
- Particulate Matter (https://www.epa.gov/pm-pollution)
- WHO Air Quality Guidelines ( http://www.who.int/airpollution/en/)

## Recommended Reading

- Air Pollution. (ISBN: 9780761432203)
- Air Pollution: Measurement, Modelling and Mitigation (ISBN: 978-0415479325)

## Optional Writing Activity

- Write a letter to your local politician about ways air pollution can be reduced in your community.

## For Teachers:
## Teacher Resource

### ◆ Lesson Goal
The goal of this lesson is for students to design and build an outdoor air pollution detector out of everyday materials.

### ◆ Lesson Objectives
Students will:
- Design and build an outdoor air pollution detector
- Test and refine their designs
- Communicate their design process and results

### ◆ Materials
- Construction paper, cardboard, plastic wrap, wax paper, fabric, felt, coffee filters, index cards, paper plates, paper cups, scissors, double sided tape, petroleum jelly, Karo syrup, hangers, string, rulers, hand lenses, graph paper, microscopes or digital camera if available (optional)

### ◆ Procedure
1. To begin, ask students to share some sources of air pollution, how they think it is measured and how it impacts society. Discuss that engineers design instruments that can detect the presence of different types of pollutants in the air.
2. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
3. Divide students into groups of 2-3 students, providing a set of materials per group.
4. Explain that each team must design a particulate air pollution detection device. It must have a flat collection area which is at least 5 cm x 5 cm. The device should have relative protection from the elements and should be able to be secured.
5. Students then meet and develop a plan for their device. They agree on materials they will need, write or draw their plan, and then present their plan to the class.
6. Next, student groups execute their plans. They may need to rethink their plan, request other materials, trade with other teams, or start over.
7. Each team should place their detector at a different location around the school (near school buses, parking lot, playing field etc.).
8. After 72 hours, students can examine the particulate matter collected by their devices using hand lenses (or microscopes/digital cameras, if available).
9. Students should record and describe all the different types of particles they see (dust, pollen, dirt etc.) in terms of size, color, shape and texture.
10. Students should then create a grid of 1 cm squares over their device's collection area with string, securing it with tape. They should then count the number of particles in five random squares and take an average. Students can then compare and graph findings for the different locations tested by the class.
11. Students can then develop a scale to rate air quality/air pollution at the different locations tested around the school.
12. Teams complete an evaluation/reflection worksheet, and present findings to class.
13. This project can be extended over the school year for additional data analysis.

### ◆ Time Needed
2-3 forty-five minute class periods.

## *Student Resource: Air Pollution*

### ◆ Air Pollution

Air is essential to life. The air around us is comprised primarily of the elements nitrogen and oxygen. When other substances such as chemicals, natural materials, or particles enter the air, this is known as air pollution. Air pollution can occur both indoors as well as outdoors. It can have both natural and human induced causes. Air pollution impacts humans, animals and the environment in a number of different ways.

Air pollution can be the result of a number of different types of human activity. When pollutants from smokestacks and automobile emissions are released into the air, chemical reactions occur in the atmosphere which can lead to a number of problems. Smog occurs when pollutants in the air mix with ozone, causing hazy atmospheric conditions and respiratory problems in humans. Smog typically occurs over large cities or industrial areas. London, Los Angeles, Mexico City and Southeast Asia all have significant problems with smog. Acid rain occurs when pollutants such as sulfuric acid mix with water in the air, causing rain and snow to become too acidic. This acidity is very harmful to the environment and as a result kills plants, trees, fishes and animals. When fuels are burned for energy in automobiles, factories, fireplaces and barbecues, tiny particles are released into the air. These particles make up what is known as particulate matter pollution.

### ◆ Particulate Matter

Pollution caused by particles, also known as particulate matter, consists of a mixture of small particles and liquid droplets in the air. Particulate matter can include both coarse particles and fine particles. Coarse particles are larger than 2.5 microns but less than 10 microns in diameter (A human hair is roughly 70 microns in diameter). These can include smoke, dust, dirt mold and pollen. Fine particles are less than 2.5 microns in diameter. Fine particles can include toxic compounds and heavy metals.

Particulate pollution, particularly fine particle pollution, is very harmful to humans when inhaled. Particulate matter disrupts ecosystems. Particles in the air also cause hazy atmospheric conditions. The amount of particulate matter in the air varies depending on the time of the year and the weather. For example, the amount of particulate matter may be higher in the winter due to an increase in the use of fireplaces and wood burning stoves. Particulate pollution is also categorized by its source. Primary particles can be traced directly to their sources, such as smokestacks, idling vehicles or power plants. Secondary particles on the other hand, are created through reactions in the atmosphere and are therefore much more difficult to trace.

## Student Resource (continued):

### ◆Particle Matter Samplers and Counters

Particulate matter samplers collect particulate matter to determine how much is in the air and so that particles may be examined later in a laboratory. One type of particulate matter sampler draws air through a filter attached to a glass tube. The weight of the filter is taken before the sampling occurs. After the filter has collected some particles, it is then weighed again. The amount of particulate matter is calculated using the weight of the particulate matter collected by the filter and the amount of air sampled. Another type of particulate matter sampler collects particulate matter on a reel of filter tape, which is weighed before and after the sampling.

Instruments known as particle counters detect and count the number of particles in the air. Aerosol particle counters count the number of particles in the air and measure their size. Light blocking particle counters detect the amount of particles in the air by passing light through an air sample and measuring how much of that light is being blocked by the particles. This method can be used to assess particles that are larger than 1 micrometer. Smaller particles (larger than .05 micrometer) can be detecting using the light scattering method. This method measures how much light is scattered by particles in an air sample. Lasers can also be used to illuminate an air sample so the silhouettes of particulate matter can be captured with a digital camera for magnification and examination.

### ◆ Rating Air Quality

The World Health Organization has established guidelines for air quality based on the negative health effects of pollution on humans. Many countries have established scales that rate the quality of the air in a particular region at a given time. These scales rate air quality based on the concentration of pollutants in the air, but vary by location and also as to which type of pollution they assess. Despite evidence of the negative impact of air pollution on health, many countries still do not monitor and rate air quality.

In Mexico City, the Sistema de Monitoreo Atmosférico de la Ciudad de México (SIMAT) uses a rating system known as Índice Metropolitano de la Calidad del Aire (IMECA) to measure concentrations of pollutants including fine particulate matter, carbon monoxide, sulphur dioxide, nitrogen dioxide and ozone.  A 200 point rating scale consisting of five categories ranging from "buena" (good) to "extremadamente mala" (extremely bad) is used to rate and describe air quality conditions. In the United States, the Environmental Protection Agency uses the Air Quality Index which examines concentrations of these same pollutants and assigns a rating on a scale of 0 to 500. Within this scale there are six categories that describe the quality of the air ranging from "Good" to "Hazardous". The Hong Kong Environmental Protection Department also rates air pollution on a 500 point scale with five categories ranging from "low" to "severe" based on concentrations of pollutants in the air. In March 2010, Hong Kong's air pollution hit record levels (over 500!) after a serious sandstorm occurred in southern China.

## *Student Worksheet:*

◆ You are a team of engineers who have been given the challenge to design a device that can detect the presence of particulate pollutants outside of your school. The device must have a flat collection area which is at least 5 cm x 5 cm. The device needs to have relative protection from the elements and should be able to be secured (so it does not blow away).

◆ Planning Stage
Meet as a team and discuss the problem you need to solve. Then develop and agree on a design for your air pollution detector. You'll need to determine what materials you want to use.

Draw your design in the box below, and be sure to indicate the description and number of parts you plan to use. Present your design to the class.

You may choose to revise your teams' plan after you receive feedback from class.

| Design: |
| --- |
| |

## Student Worksheet (continued):

◆ Construction Phase

Build your air pollution detector. During construction you may decide you need additional materials or that your design needs to change. This is ok – just make a new sketch and revise your materials list.

◆ Testing Phase

Each team will test their air pollution detector by placing it at a different location around their school. After 72 hours, check to see whether your tester collected any particles. Use a hand lens, microscope, or digital camera to examine the particles collected. Document the different types of particles you see (e.g. dust, pollen, dirt etc) as well as their size, color, shape and texture.

Use string to create a grid of 1 cm squares over your device's collection area, securing it with tape. Count the number of particles in five random squares. If there are too many to count, estimate. Calculate the average number of particles per square. Compare and graph the findings for the different locations tested in the class. Develop a scale to rate air quality/air pollution at the locations tested around your school.

◆ Evaluation Phase

Evaluate your teams' results, complete the evaluation worksheet, and present your findings to the class.

Use this worksheet to evaluate your team's results in the "Pollution Patrol" Lesson:

1. Did you succeed in creating an air pollution detector that could detect the presence of particles in the air? If not, why did it fail?

2. Did you decide to revise your original design or request additional materials while in the construction phase? Why?

3. Did you negotiate any material trades with other teams? How did that process work for you?

## Student Worksheet (continued):

4. If you could have had access to materials that were different than those provided, what would your team have requested? Why?

5. Do you think that engineers have to adapt their original plans during the construction of systems or products? Why might they?

6. If you had to do it all over again, how would your planned design change? Why?

7. What designs/methods did you see other teams try that you thought worked well?

8. Do you think you would have been able to complete this project easier if you were working alone? Explain…

9. What type of particulate pollution did you find the largest quantity of? Why do you think that is?

10. What do you think can be done to reduce particulate pollution around your school?

## *For Teachers:*
## *Alignment to Curriculum Frameworks*

**Note:** Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆**National Science Education Standards Grades K-4 (ages 4 - 9)**

**CONTENT STANDARD A: Science as Inquiry**

As a result of the activities, all students should develop

- Abilities necessary to do scientific inquiry

**CONTENT STANDARD D: Earth and Space Science**

As a result of the activities, all students should develop an understanding of

- Changes in the earth and sky

**CONTENT STANDARD E: Science and Technology**

As a result of the activities, all students should develop

- Abilities of technological design
- Understanding about science and technology

**CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of the activities, all students should develop an understanding of

- Personal health
- Changes in environments
- Science and technology in local challenges

◆**National Science Education Standards Grades 5-8 (ages 10 - 14)**

**CONTENT STANDARD A: Science as Inquiry**

As a result of the activities, all students should develop

- Abilities necessary to do scientific inquiry

**CONTENT STANDARD E: Science and Technology**

As a result of the activities, all students should develop

- Abilities of technological design
- Understanding about science and technology

**CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of the activities, all students should develop an understanding of

- Personal health
- Populations, resources and environments
- Science and technology in society

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

**CONTENT STANDARD A: Science as Inquiry**

As a result of the activities, all students should develop

- Abilities necessary to do scientific inquiry

## *For Teachers:*
## *Alignment to Curriculum Frameworks*

◆**National Science Education Standards Grades 9-12 (ages 14-18)**

**CONTENT STANDARD E: Science and Technology**

As a result of the activities, all students should develop

- Abilities of technological design
- Understanding about science and technology

**CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of the activities, students should develop an understanding of

- Personal and community health
- Environmental quality
- Natural and human-induced hazards
- Science and technology in local, national, and global challenges

◆**Next Generation Science Standards Grades 3-5 (Ages 8-11)**

**Earth and Human Activity**

Students who demonstrate understanding can:

- 4-ESS3-2. Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.

**Engineering Design**

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆**Next Generation Science Standards Grades 6-8 (Ages 11-14)**

**Earth and Human Activity**

Students who demonstrate understanding can:

- Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

**Engineering Design**

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

## *For Teachers:*
## *Alignment to Curriculum Frameworks*

◆**Next Generation Science Standards - Grades 9-12 (Ages 14-18)**

**Engineering Design**

Students who demonstrate understanding can:

- HS-ETS1-2.Design a solution to a complex real-world problem by breaking it down into smaller, more manageable problems that can be solved through engineering.

◆ **Principles and Standards for School Mathematics**

**Number and Operations Standard**

- Instructional programs from prekindergarten through grade 12 should enable all students to:
  - Compute fluently and make reasonable estimates

**Measurement Standard**

- Instructional programs from prekindergarten through grade 12 should enable all students to:
  - Apply appropriate techniques, tools, and formulas to determine measurements.

**Data Analysis and Probability Standard**

- Instructional programs from prekindergarten through grade 12 should enable all students to:
  - Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them
  - Select and use appropriate statistical methods to analyze data
  - Develop and evaluate inferences and predictions that are based on data

**Process Standard (Representation)**

- Instructional programs from prekindergarten through grade 12 should enable all students to:
  - Create and use representations to organize, record, and communicate mathematical ideas
  - Use representations to model and interpret physical, social, and mathematical phenomena

◆ **Common Core State Standards for School Mathematics Grades 2-8 (ages 7-14)**

**Measurement and data**

- Measure and estimate lengths in standard units.
  - CCSS.Math.Content.2.MD.A.1 Measure the length of an object by selecting and using appropriate tools such as rulers, yardsticks, meter sticks, and measuring tapes.
  - CCSS.Math.Content.2.MD.A.3 Estimate lengths using units of inches, feet, centimeters, and meters.

## *For Teachers:*
## *Alignment to Curriculum Frameworks*

◆ **Common Core State Standards for School Mathematics: Content (ages 7-10)**

**Statistics & Probability**

- Use random sampling to draw inferences about a population.
  - CCSS.Math.Content.7.SP.A.2 Use data from a random sample to draw inferences about a population with an unknown characteristic of interest. Generate multiple samples (or simulated samples) of the same size to gauge the variation in estimates or predictions.

◆ **Standards for Technological Literacy - All Ages**

**Design**

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.