Shining Light on Pollution – Build Your Own Particle Sensor

Overview:

Target Age Range: 5th -12th grades

Estimated Time: 1 hour

Objective: Teach the basics about particulate matter air pollution and electronics. In addition, work on problem solving and other science, technology, engineering, and math (STEM) skills.

Alignment with LSS – Science:

Potential Anchor Phenomenon: The World Health Organization (WHO) estimates that in the year 2012 ambient air pollution was responsible for 3 million deaths. (http://www.who.int/gho/phe/outdoor_air_pollution/en/)

Potential Performance Expectations*:

HS-ESS 3-4; HS-ESS 3-2; HS-PS 2-5; HS-PS 3-3; 6-MS-PS 4-2

*The performance expectations are only partially addressed with this activity.

The materials we are using were purchased with an outreach and education grant from the International Society for Optics and Photonics (SPIE). The activity is based of the "Build Your Own Particle Sensor" activity developed by the United States Environmental Protection Agency (US EPA). The Louisiana State University Superfund Research Center (LSU SRP) is supported by a grant from the National Institute of Environmental Health Sciences (NIEHS).

LSU | Superfund Research Center

SPIE. CONNECTING MINDS. ADVANCING LIGHT.

Background Information: Particulate Matter

Particle pollution (also called particulate matter or PM) is the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope…These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. (http://www.epa.gov/pm/basic.html)

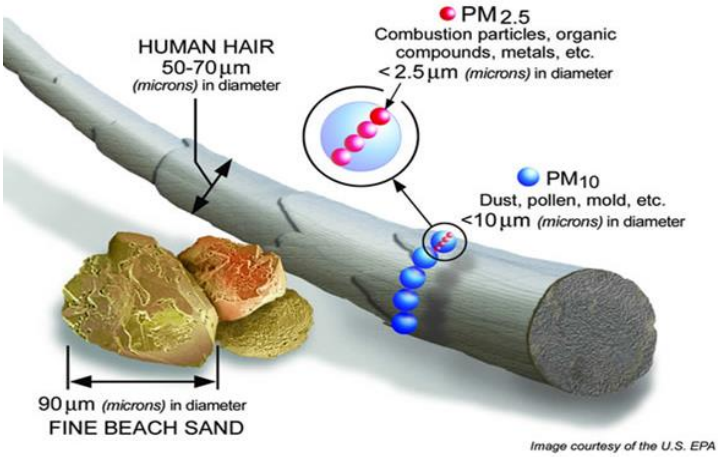


Image courtesy of the U.S. EPA

How small is 2.5 micrometers?

Particle pollution includes 'inhalable coarse particles,' with diameters larger than 2.5 micrometers and smaller than 10 micrometers and 'fine particles,' with diameters that are 2.5 micrometers and smaller. Think about a single hair from your head. The average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle.

Where do you think PM comes from?

Some particles, known as primary particles are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Others form in complicated reactions in the atmosphere of chemicals such as sulfur dioxides and nitrogen oxides that are emitted from power plants, industries and automobiles. These particles, known as secondary particles, make up most of the fine particle pollution in the country. EPA regulates inhalable particles (fine and coarse). Particles larger than 10 micrometers (sand and large dust) are not regulated by EPA.

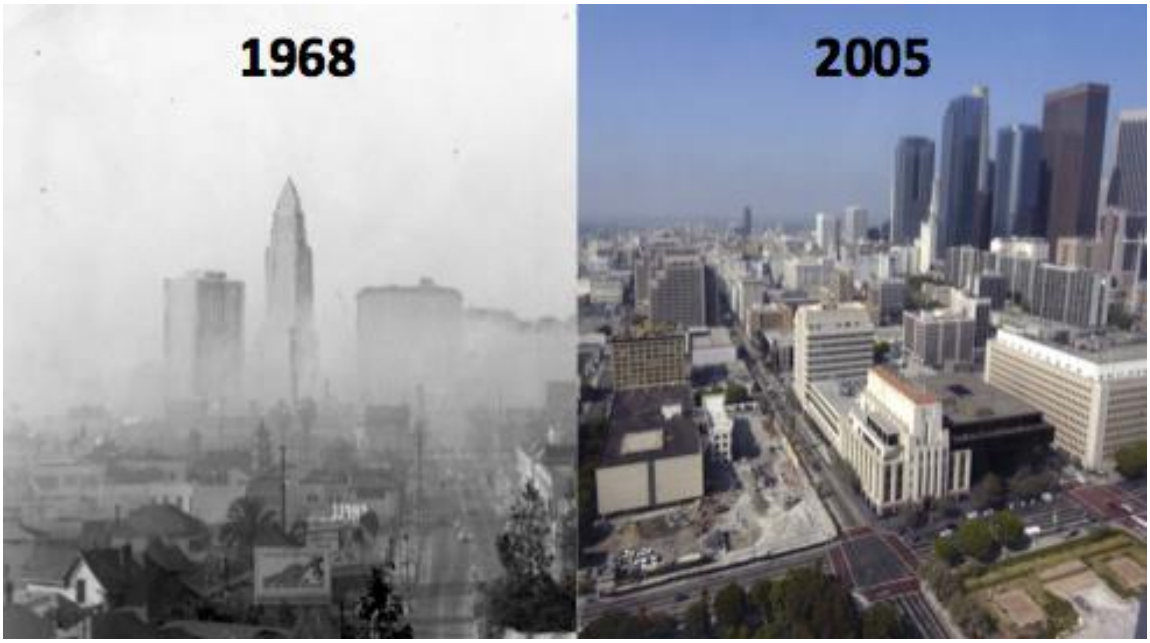
Why is PM pollution bad?

• **Health:** Particle pollution contains microscopic solids or liquid droplets that are so small that they can get deep into the lungs and cause serious health problems. The size of particles is directly linked to their potential for causing health problems. Small particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream http://www.epa.gov/pm/health.html.

• **Visibility Impairment:** Fine particles (PM2.5) are the main cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas

• **Environmental Damage:** Particles can be carried over long distances by wind and then settle on ground or water. The effects of this settling include: making lakes and streams acidic; changing the nutrient balance in coastal waters and large river basins; depleting the nutrients in soil; damaging sensitive forests and farm crops; and affecting the diversity of ecosystems.

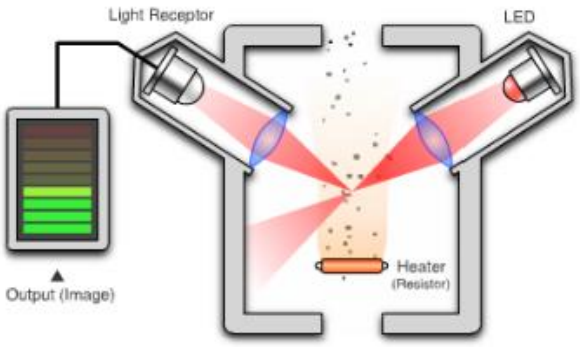
• **Aesthetic damage:** Particle pollution can stain and damage stone and other materials, including culturally important objects such as statues and monuments. An example is Hadrian's Arch, built in Athens Greece in 131 AD. It has been discolored by soot from the city.



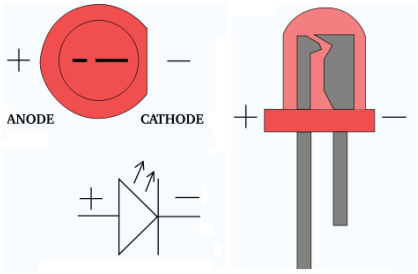
Images courtesy of the Cooperative Institute for Research in Environmental Sciences (CIRES) at the University of Colorado Boulder and Shari Shapiro at the Green Building Law Blog (http://www.greenbuildinglawblog.com)

Background Information: Basic Electronics

Particulate Matter (PM) Sensor: This image shows how the PM sensor works. Since warm air rises, a heater causes air to flow through the sensor. This is why the sensor must be mounted vertically. An LED shines light on the particles and the amount of light that is deflected by the particles is measured by a light receptor. This type of particle detection generally sees particles greater than 1 micrometer, which makes the sensor more sensitive to larger particles like dust and less sensitive to very small particles formed in smoke.
Image: www.shinyei.co.jp



LED: Inside each LED is a small bit of chemical that when electrons are passed through, it emits radiation (i.e., light). Be aware that an LED is a diode, meaning that it is polarized. Current can only go from the anode (positive end) to the cathode (ground, or negative end)… Note that the two wires on the LED are different lengths. The longer wire is always + and the shorter is -.
Image: https://www.societyofrobots.com/)

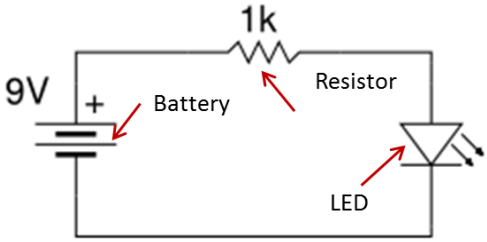


Resistor: If there is too much current the LED will glow too brightly and will be damaged. The battery will also run out very quickly. The resistor resists current of electrons resulting in a lower current. Think of water flowing when you think of current. Inserting a resistor is like inserting a smaller pipe in the middle of a river. The stripes on the resistor are a code for the resistance and tolerance values of the resistor.

Breadboard: This is a tool used to put together temporary circuits. Wires and components are pressed into the holes to make different circuits and can easily be removed. The holes are connected as shown; the 5 across on the left, the 5 across on the right and down the 2 columns on the two edges of the board. Plugging wires into two connected holes is the same as touching the two wires together.

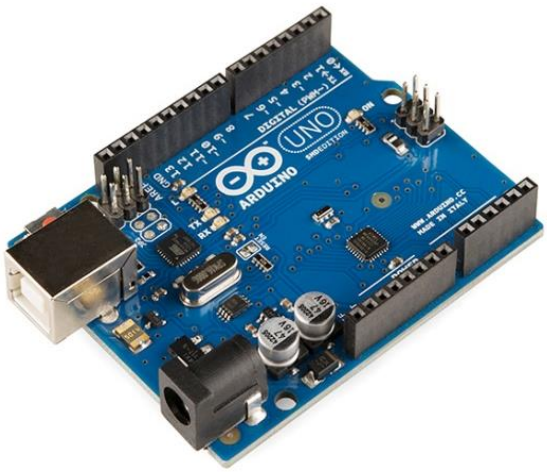
Basic circuit: An electric circuit is like a pathway made of wires that electrons can flow through. A battery or other power source gives the force (voltage) that makes the electrons move. When the electrons get to a device like a light bulb, your computer, or a refrigerator, they give it the power to make it work. To make a circuit, current must pass from power to ground. Ground is a reference voltage of zero and in some cases means the circuit is actually connected to the earth. Just like water flows from higher elevation to lower elevation electrical current also flows from higher voltage to lower voltage.

Reading a Circuit Diagram (also called a schematic diagram)



This circuit diagram tells us (clockwise from the battery): Connect the positive terminal of the battery to a 1 k-ohm resistor. Connect the other lead of the resistor to the anode of the LED. Connect the cathode of the LED to the negative terminal of the battery.

Arduino: This is an Arduino; it is a mini computer that will be used to run our project. It is an open source platform which means the code and specifications are open and free to the public and people are allowed to build and even sell their own versions. Note: When the Arduino is connected to a laptop or other device with power, the laptop can serve as a power source. There are many excellent sources of information for Arduinos including https://www.arduino.cc/ and https://learn.adafruit.com/category/learn-arduino. The East Baton Rouge Public Library also has Arduino kits and several project books that can be checked out.



How the Arduino Code works: Code has been written and installed on your Arduino to run the PM sensor you will build. Basically the Arduino is checking the particle sensor continuously to see whether it is detecting particles or not. The amount of PM pollution is determined based on the amount of time the sensor is detecting particles. The Arduino then lights up the LEDs based on how many particles are seen. 1 LED for a low number of particles, 2 LEDs for a moderate amount of particles, and 3 LEDs for a high amount of particles. You can alter the code to add LEDs or make the sensor more sensitive (have more LEDs light up for the same number of particles detected).

To run the code you must download and install the Arduino software (IDE). The Arduino IDE is open source, meaning that it is freely available, and can be found here: https://www.arduino.cc/en/Main/Software

Additional Resources:

Supplies: Almost all the supplies for this activity can be purchased from a company called Adafruit (this is not an endorsement of the company). The table below lists the supplies and cost as of February 2018. You will also need at least 1 USB cable to load the code onto the Arduinos as well as materials to mount the sensor.

Item	Cost	Supplier
Arduino Uno R3	24.95	https://www.adafruit.com/
Dust Sensor (PPD42NS)	11.50	https://www.seeedstudio.com/
Breadboarding wire bundle	4.95	https://www.adafruit.com/
Half-Size Breadboard	5.00	https://www.adafruit.com/
Diffused 5 mm Red LED	4.00 (pack of 25)	https://www.adafruit.com/
Through hole resistors (1K Ohm)	0.75 (pack of 25)	https://www.adafruit.com/
9 V Battery holder/ clip	3.95/ 2.95	https://www.adafruit.com/

Instructions developed by the US EPA: This is a wonderful resource about this activity that includes some trouble shooting tips for the Arduino code: https://www.epa.gov/sites/production/files/2014-12/documents/sensor-kit-instructions.pdf