

Measuring Air Quality Improvements from Vegetative Barriers: Activities and Lessons for K-5 Educators

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Introduction

This unit has been designed by the United States Environmental Protection Agency (EPA) as a teaching aid on the topic of air quality; particularly, investigating the role vegetative barriers play in improving air quality for surrounding areas. Each lesson aligns with the Next Generation Science Standards (NGSS) in the table below and may also align with specific state standards for Mathematics, Art, and other content. This unit is designed to engage learners throughout the higher levels of Bloom's Taxonomy with each lesson incorporating data collection and analysis by students. These lessons can be modified as needed for classrooms with varying learning abilities.

The lessons here were originally designed for use with sensor packages available as part of EPA research projects partnering with communities in [Oakland, California](#) and Detroit, Michigan. The sensors described in detail in these lessons are not available for public use, however, the lessons can be adapted to other sensors technologies and locations. Some sensors may be available through air sensor loan programs for communities (information available <https://www.epa.gov/air-sensor-toolbox/air-sensor-loan-programs>) or by purchase from a number of commercial vendors.

There are four major introductory level topics which students can investigate: air quality, sensor use, vegetative barriers, and the impact of emissions on health. Each lesson contains an in-class activity as well as a field experience activity which requires the use of stationary and/or mobile sensors. The individual lessons span multiple K-5 grades. Each lesson contains lesson goals, key vocabulary, and a teacher background section. Please note that additional instructional materials such as presentation slides, note taking sheets, or content readings are not included in this unit. Each grade level and teacher may choose to present the information in any way they feel is appropriate for their unique classroom situation.

Table 1. *Next Generation Science Standards (NGSS)*

K	1	2	3	4	5
K-ESS2-2: Earth's Systems	K-2-ETS1-1: Engineering Design	K-2-ETS1-1: Engineering Design	3-ESS3-1: Earth and Human Activity	4-ESS3-2: Earth and Human Activity	5-ESS3-1: Earth and Human Activity
K-ESS3-3: Earth and Human Activity	K-2-ETS1-3: Engineering Design	K-2-ETS1-3: Engineering Design	3-5-ETS1-3: Engineering Design	3-5-ETS1-3: Engineering Design	3-5-ETS1-3: Engineering Design
K-2-ETS1-1: Engineering Design					
K-2-ETS1-3: Engineering Design					

Project Summary

Measuring Air Quality Improvements from Vegetative Barriers

What is the Vegetative Barrier Project?

The United States Environmental Protection Agency (EPA) is interested in ways to reduce human exposure to air pollution from sources like cars and trucks on busy highways. Vegetative barriers, which consist of trees and bushes, can help improve air quality – particularly when paired with a noise barrier. These lessons have been developed in support of two EPA projects. Brookfield Elementary School in Oakland, California, has an ongoing effort to make the campus greener and has installed a vegetative barrier making it a great place to investigate the air quality benefits as well as engage students in important conversations about the environment and human health. Kemeny Park in

Detroit, Michigan is another place where EPA is working with the community to investigate air quality benefits of vegetative barriers at a recreation center adjacent to Interstate Highway 75 (I-75).



Vegetative and noise barriers in Oakland, California



The Portable Air Quality Sampler (Briefcase) takes mobile measurements of air pollution

Why is this project important?

Air quality is incredibly important to human health. People exposed to air pollution might experience health issues like asthma and difficulty breathing. Children, the elderly, or those with cardiovascular or respiratory disorders are particularly sensitive to pollutant exposure. Air pollution near roads has also been associated with adverse birth outcomes, including pre-term birth and low birth weight. The EPA is researching ways to improve air quality by testing this unique method of using trees and bushes to filter and disperse air pollutants that might be harmful to human health.

How will teachers and students be involved?

Teachers and staff at schools and other locations affected by near-road air pollution will learn how to use air sensors to measure air quality and see what effect the vegetative barrier is having as the trees and bushes grow larger over time. Students will have the opportunity to use the sensors to engage in real life learning scenarios for the STEM (Science, Technology, Engineering and Mathematics) subjects as well as other academic areas.



The Solar Powered Air Quality (Birdhouse) takes stationary measurements of air pollution

Resumen del Proyecto

Midiendo las Mejoras en la Calidad del Aire a Partir de Barreras Verdes

¿Qué es el Proyecto de Barreras Verdes?

La Agencia de Protección Ambiental de los Estados Unidos (EPA, por sus siglas en inglés) está interesada en formas de reducir la exposición de las personas a la contaminación del aire proveniente de fuentes como automóviles y camiones en las carreteras muy transitadas. Las barreras verdes, que consisten en árboles y arbustos, pueden ayudar a mejorar la calidad del aire, especialmente cuando se combina con una barrera de control al ruido. Estas lecciones se han desarrollado en apoyo de dos proyectos de la EPA de los Estados Unidos. La Escuela Primaria Brookfield, en Oakland, California, en su esfuerzo continuo para hacer que el campus sea más ecológico es un excelente lugar para investigar beneficios de calidad del aire y para involucrar a los estudiantes en conversaciones importantes sobre el medio ambiente y la salud humana. Kemeny Park en Detroit, Michigan, es otro lugar donde la EPA también está trabajando con la comunidad para investigar los beneficios de las barreras verdes en la calidad del aire en un centro recreativo junto a la carretera interestatal 75 (I-75).



Barreras verdes y barreras para el control de ruido en Oakland, California



El Sensor Portátil tomará mediciones móviles de contaminantes en el aire.

¿Por qué es importante?

La calidad del aire es increíblemente importante para la salud humana. Las personas expuestas a la contaminación del aire pueden tener un mayor riesgo de problemas de salud, como asma y dificultades para respirar. Los niños, los ancianos o aquellos con trastornos cardiovasculares o respiratorios son particularmente sensibles a la exposición a las contaminantes del aire. La EPA está investigando formas de mejorar la calidad del aire con este método único utilizando árboles y arbustos para filtrar y dispersar los contaminantes del aire que podrían ser dañinos para la salud humana.

¿Cómo se involucrarán los estudiantes y maestros?

Los maestros y el personal de Brookfield aprenderán cómo usar sensores de aire para medir la calidad del aire y ver el efecto que tiene la barrera verde mientras crecen los árboles y arbustos. Los estudiantes tendrán la oportunidad de utilizar los sensores para participar en escenarios de aprendizaje de la vida real para las asignaturas STEM (Ciencias, Tecnología, Ingeniería y Matemáticas), así como otras áreas académicas.



El Sensor "Casa de Pájaros" tomará mediciones estacionarias de contaminantes en el aire.

Background for Teachers: Vegetative Barrier & Air Quality Sensor Project



Why Vegetative Barriers?

Research shows roadside barriers can change the movement of air pollution from sources like busy roadways. If the wind is carrying air pollution from a busy road toward areas where people live, work and study, solid noise barriers and vegetation can be built to help reduce exposures to those pollutants. This is important because there may be high levels (concentrations) of air pollution near sources like large transportation corridors - such as highways - and the air pollution can pose health risks for people near those sources.



What are our Sensors and What do they Measure?

Sensors are tools that can detect and measure air pollutants. The EPA has developed two sets of unique sensor packages. These packages were created to hold multiple sensors: The Solar Powered Air Quality (S-PAQ) Birdhouse and the Portable Air Quality Sampler (PAQS) Briefcase. These packages also include batteries (and other ways to provide power to the sensors) and protect the sensors from possible damage.

EPA developed these sensor packages for barrier research projects in Oakland, California. The sensor technologies inside of these packages are being used in other locations, like in Detroit, Michigan.

Some more information about the projects can be found here:

- <https://www.epa.gov/sciencematters/researchers-assess-roadside-vegetation-barriers-suite-air-monitors>
- www.epa.gov/innovation/building-capacity-measure-air-pollution-mitigation-strategies-schools

The **Birdhouse** has its own power source – solar panels -- and is intended to take stationary measurements for a specific area over longer periods of time. It also includes equipment to measure wind speed and direction and temperature. It is called the Birdhouse because of its resemblance to an actual birdhouse, and the anemometer (to measure wind speed and direction) was chosen in part because of its slight resemblance to a bird.

The **Briefcase** is for mobile measurements, meaning it can take measurements over a larger space by carrying it around or stopping briefly to take measurements. The Briefcase is battery powered and requires charging.

Both the Briefcase and the Birdhouse contain sensors which measure the same pollutants: Nitrogen Dioxide (NO₂) and Black Carbon (BC). While the “packaging” looks different, the sensors that are inside are commercially available and widely used for many research purposes and other citizen science applications. In fact, while other places like Detroit may not have access or limited access to sensors packages such as the Briefcase and a Birdhouse, the sensors inside of the packages can be available for citizen science applications. There are also readily available graphing tools, like EPA’s RETIGO tool discussed later in Lesson #1, which can be used to visually display the data collected from the individual instruments.

“**Nitrogen Dioxide (NO₂)** is one of a group of gases called nitrogen oxides (NO_x). While NO_x gases are harmful to human health and the environment, NO₂ is of greater concern” to human health.

<https://www.epa.gov/no2-pollution>

NO₂ can affect the human respiratory system by irritating the airways. Being exposed to high concentrations of NO₂ for long periods may contribute to the development of asthma and make people more susceptible to respiratory infections.

The sensors measure **concentrations** of NO₂ in the air we breathe. In this case, the sensors measure parts per billion (**ppb**). 1 ppb means 1 part of NO₂ to 1 billion parts of air.

Black Carbon (BC) is part of what is called **Particulate Matter**. It is the part of Particulate Matter that is the most strongly light-absorbing, leading to the name “black” carbon. It is also strongly linked to mobile source emissions. <https://www3.epa.gov/airquality/blackcarbon/>

“Particulate matter (PM), also known as particle pollution, is a complex mixture of extremely small particles and liquid droplets that get into the air. Once inhaled, these particles can affect the heart and lungs and cause serious health effects.” <https://www.epa.gov/pm-pollution>

Black carbon is sometimes called soot and can be measured in two ways. BCIR are measurements at the Infrared (IR) end of the visible light spectrum, while BCUV are at the ultraviolet end. The BCIR measurements are most representative of the actual black carbon (soot), while the BCUV can include other particles that include organic compounds.

The sensors measure **concentrations**. In this case, the weight or mass of the black carbon in a volume of air. The units for BC are nanograms per meter cubed (ng/m³). A nanogram is one billionth of a gram. A meter cubed is a volume that is 1 meter wide by 1 meter long by 1 meter high.

How Can Teachers Use This Information in K-5 Classrooms?

This set of activities and lessons has been developed specifically for use with the S-PAQ Birdhouse and PAQS Briefcase sensors. Most of the materials have been developed with a focus on Brookfield Elementary and to understand and measure changes over time that may results from changes in sources but also the benefits from the vegetative barriers as they grow. However, the lessons and activities can be adapted by using the black carbon and NO₂ sensor technologies on their own for other near-road situations in other cities and communities. The lessons will include two components.



IN-CLASS ACTIVITY

This indicates a classroom-based activity to improve students understanding of vegetative barriers, air pollution, and measurements.



FIELD ACTIVITY

This indicates an activity, such as taking measurements, requiring teachers and students to go outside to various parts of the school. None of the activities require leaving school property.

Using the PAQS Briefcase Sensor for Data Collection

Step One: Activating the Sensors

It is recommended to activate the device 10 minutes before class, as the unit needs to warm up. **For the device to function properly, you must turn on the BC sensor separately from the entire unit** (see Figure 1). Otherwise, only readings from the NO₂ sensor will be collected, and the BC readings will not appear on the screen.

1. Open the briefcase (see Figure 1)
2. Turn on the BC sensor by pressing any of the three buttons on the **end of the BC sensor** for two seconds (Figure 1).
3. A light will turn on and a small screen on the end of the sensor will read “Begin Measurements.”
4. **Press the center button to confirm this action.** You may hear the sensor turn on.
5. Close and lock the case.
6. Turn on the entire unit by **flipping the large Power switch on the side of the briefcase** (see Figure 2). This will turn the PAQS on, and the measurement screen on the outside of the briefcase will light up.

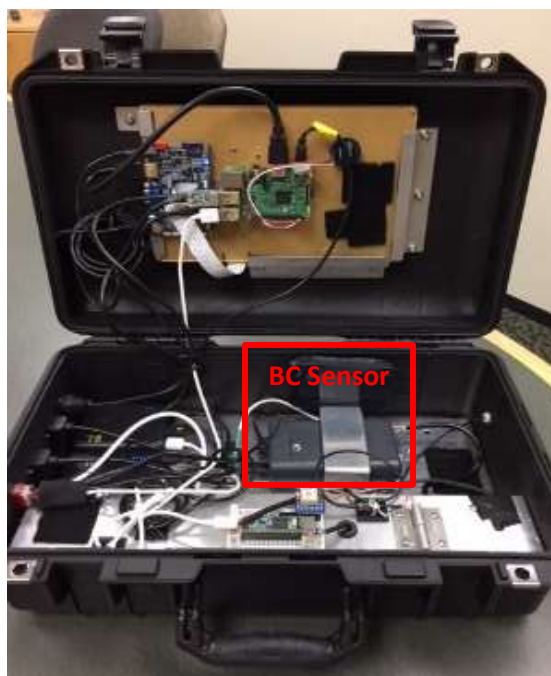


Figure 1 Sensors inside of the Briefcase

Step Two: Navigating the Screens

Once the device is powered on, you will arrive at a measurement screen (Figure 3). Please note that **the device will need at least ten minutes to warm up**.

1. To switch between various screens, **double tap** the “HOME” button.
2. Double tap until you are able to see the **measurement screen** with data readings as shown here. Black Carbon concentrations will be on the left part of the screen, NO₂ concentrations will be on the right part of the screen.
3. Double tap **GPS** on the lower right-hand side to get GPS readings for your location. You will use these readings for some of the measurement exercises.
4. Once the device has had at least ten minutes to warm up, you can begin collecting data! Take the sensor to various stations to get measurements for Black Carbon (BC) and Nitrogen Dioxide (NO₂).



Figure 2 Side of Briefcase



Figure 3 View of measurement screen

Step Three: Collecting Data

Students may not be familiar with this type of data display, so it is important to first let them explore what the graphs are displaying. This is easier to do indoors, rather than out of doors.

1. Discuss with students the time increments over which data is being collected.
2. Ask them to make observations about the difference in the measurements for each time stamp.
3. Do the numbers change a lot or a little? What is the highest level they see? What is the lowest level? How does that compare to the numbers on the lower part of the screen that give the 10-minute averages?
4. Is one BC reading (on the left part of the screen) higher than the other? Explain that these are two different ways to measure the same pollutant.
5. Are they noticing any patterns or trends?

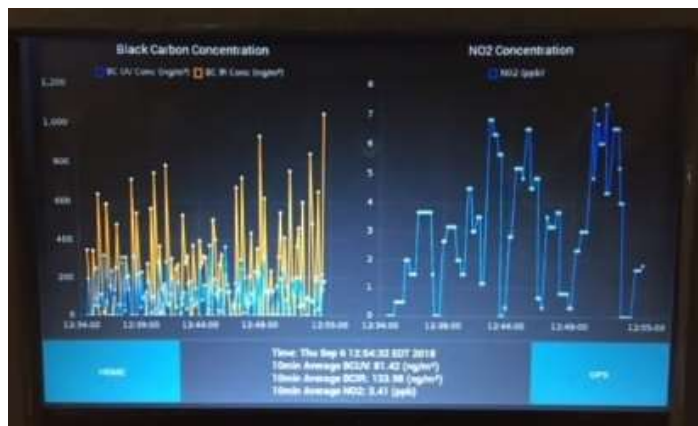


Figure 4 Close up of screen with BC (left) and NO₂ (right) concentrations.

Once students get some experience looking at the display and understanding what they are reading, you may go outside to begin the data collection field activities described in the lessons. On the back of this document, you can also find a copy of the observation sheet with examples filled in.

Step Four: Turning off the Sensor

1. Once data collection is complete, open the briefcase and press either the left or right button on the end of the BC sensor (see Figure 1)
2. Press this button (you may have to press it more than once) until you see the option “**Turn Off**”
3. When you see this option, press the **center button** to select. You will hear the system power down.
4. Close and lock the briefcase. Turn off the PAQS by **flipping the outside switch** (Figure 2) **on the briefcase to the “Off” position**.
5. Remember to fully charge the system once you are finished. Plug in both cords to **charging ports** (Figure 2) on the side of the PAQS.

Observation Data Sheet - example

Student Activities While Collecting Data (Example Sheet)

NOTE TO Teachers: When collecting data, allow students to work in groups. Since data collection/viewing may be difficult for large groups to do at one time, we recommend having one student as data collector to record the observations from the sensor at each measurement station. While your data collector gathers the information from the sensor, have the remaining group members document the observations requested at each station. Have handheld thermometers available for students so they can take their own temperature measurements.

Station Name & GPS Location (Latitude and Longitude)	Is the vegetative barrier visible? How does it look?	Weather Observations (Conditions, Temperature, Wind Speed/Direction, etc.)	Cloud Cover and Types	Do I smell/see any smoke, soot, or steam? Any other odors/smells?	Do I see/hear traffic?	Other Area Observations
<i>Playground near fence</i> <i>GPS location will vary among locations</i>	<i>Yes, the vegetative barrier is visible. It looks healthy; many of the trees are full and shrubs have their leaves.</i>	<i>It is sunny and hot. Temperature is 89°F</i> <i>The wind light and is coming from the roadway, toward the barrier, and then to me on the playground.</i>	<i>There are a lot of large, white, fluffy clouds in the sky</i>	<i>I saw some smoke which looked like maybe someone was burning something? It was light colored. Maybe steam.</i>	<i>Yes. I cannot see any traffic, but I can hear a lot of cars from the road.</i> <i>It sounds like a lot of large trucks are passing by.</i>	<i>There are a lot of kids playing on the playground.</i>
<i>Bus parking lot</i> <i>GPS location will vary among locations</i>	<i>I cannot see the vegetative barrier.</i>	<i>It is sunny and hot. Temperature is 91°F</i> <i>It is hotter in the parking lot than under the shade.</i> <i>There is no wind.</i>	<i>There are a lot of large, white, fluffy clouds in the sky</i>	<i>Yes, I saw some large truck go by with black soot or smoke coming out.</i>	<i>Yes. I can see some traffic. There are a lot of cars and trucks driving by.</i> <i>I see several large trucks.</i>	<i>Some of the buses are missing.</i> <i>One bus hood is still warm from where it came in recently.</i>
					<i>*Note: Depending on traffic flow and visibility, more advanced groups could count the number of cars or heavy trucks in a minute.</i>	

LESSON #1: Using Sensors to Collect Data

(instruct students with Lesson #1 before moving on to other lessons.)

TOPIC: Emissions and Air Pollutants; Data Collection & Analysis

NGSS STANDARDS

K-ESS3-3: Earth and Human Activity	Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.
K-ESS2-2: Earth's Systems	Construct an argument supported by evidence for how plants and animals (including humans) change the environment to meet their needs.
3-ESS3-1: Earth and Human Activity	Make a claim about the merit of a design solution that reduced the impacts of weather-related hazard.
4-ESS3-2: Earth and Human Activity	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
5-ESS3-1: Earth and Human Activity	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

LESSON GOALS: The student will...

- Collect and record data from the PAQS sensor.
- Discuss and record observations from collection sites.

KEY VOCABULARY: Black Carbon, Nitrogen Dioxide, Concentrations, Sensor, Measurement, Graph, Data, Latitude, Longitude

BACKGROUND FOR TEACHERS:

Scientists often collect data to better understand the topics which they are investigating. For students using the PAQS briefcase sensor, data collection and analysis will be an important

component understanding why the vegetative barrier project is being implemented at their school. Students should be given ample opportunity to use the sensors and familiarize themselves with data collection. This initial lesson can be repeated often and can be changed as needed to fit the needs/abilities/grade level of students.

Using the PAQS Sensor:

See the pages above titled, **Using the PAQS Briefcase Sensor to Collect Data**, for a brief how-to guide on the steps for using the PAQS sensor. Ensure that each step is followed for best results. This page can be printed and laminated to include with the PAQS Briefcase.

Teachers should be the ONLY people opening the device to activate the BC sensors. Please do not allow students to open the briefcase. Some lessons below will have students look inside the PAQS briefcase, but only under teacher supervision.



FIELD ACTIVITY: Using the Sensors at School

MATERIALS: Mobile Sensor; Sensor Data Sheet; Student Observation Sheet; School Map; Data Collection Sampling Plan Sheet; Pollution Sources

TEACHER INSTRUCTIONS:

***REMINDER:** Students should be supervised at all times when using sensors.*

Separate students into small groups (no more than five students per group). Give each group a map (from Google maps or another online source) of the school grounds (Supplemental Materials). Discuss as a class the areas in which you want to investigate the air quality. Take student suggestions, but also be certain to include an area near the vegetative barrier. Select FIVE sampling points at which to take measurements and then have the group come up with a sampling plan. Have them draw out the path that they will follow to go from one sampling point to another. Give each group a copy of the Data Collection Sampling Plan and a copy of the school/community map (see Supplemental Materials). Students should decide which group member will collect data from the sensor at each location, while the other group members collect observational data on the Student Observation sheet.

Once their sampling plans are complete, move to the sampling points and begin data collection. **The groups should spend about five minutes at each sampling point.** One person from each group may conduct the sensor readings at a time. The students who are recording data from the sensors should use the SENSOR DATA SHEET (see Supplemental Materials). They will record the following from the main PAQS screen:

- Start and end time for the five-minute sampling period
- GPS coordinates – latitude and longitude

- The highest and lowest measurements (for BCIR, BCUV, and NO₂) that occur over the five-minute time period. The lowest measurement may be zero, the highest measurement will be a spike.
- Note that BCIR and BCUV are both measurements of black carbon (BC) but use two different approaches.
- Ten-minute average concentration for each pollutant (for BCIR, BCUV, and NO₂), these are shown at the bottom of the PAQS screen.

The other group members will conduct observations in the area. Those students should use the STUDENT OBSERVATION SHEET. Each student should have at least one turn in collecting data from the sensor and should have multiple opportunities to make observations. Encourage them to make observations that are relevant to the following.

(a) Source of pollution: Do they hear see or traffic? Do they smell or see smoke from any burning, from any factories/industries they can see, soot/emissions from trucks, or even steam (not a source of pollution but sometimes confused as smoke or emissions)? Do they smell any other odors?

(b) Conditions that would affect the pollution as it moves from the source to where they are. Is it windy? What direction is the wind coming from? Would the vegetative barriers block the pollution from coming towards them?

A sample student observation sheet is provided with the user instructions for the sensor.



IN-CLASS ACTIVITY: Are you RETIGO?

Once scientists collect data, they often use computers to understand that data. They can use computers to graph the data or to view or “visualize” the data in different ways. For environmental data that is collected in motion, like carrying around the PAQS Briefcase, it is often helpful to see that data displayed on a map.

Students may access an EPA tool called REal Time GeOspatial viewer (RETIGO) to visualize their data. Using RETIGO, have students practice logging their data into a database. Then, discuss with the class the value of computer-based systems for scientists when they are working with large scale databases. If it is possible, you can pull up archived data from RETIGO to show examples of ways the data has been used by other people across the country.

Steps for uploading data from the PAQS to RETIGO

Remove the USB drive from the PAQS

1. On the PAQS screen, double click “Home” and from there double click to “System” (refer back to instructions on using the PAQS).
2. From that screen, double click “Unmount USB”

3. You can then remove the small USB drive found on the side of the PAQS.

Save the data to a computer

4. Connect the USB drive to a computer.
5. Navigate to the files on the USB drive. The measurements are saved as Text (.txt) files.
6. Each file will be named according to the date and time that the measurements were taken. For example, “2018_5_18_9-1-49.txt” shows data taken on May 18, 2018. The data in the text file is logged every 10 seconds. You can open the text file and see the lines of data. Just don’t edit the data.
7. Copy all the files from the day(s) that you took measurements to a folder. Don’t forget which folder you used.



Figure 5. View of side of PAQS with USB drive.

Upload the data to RETIGO

8. To access RETIGO, navigate to <https://www.epa.gov/hesc/real-time-geospatial-data-viewer-retigo>. From there, click on/select the phrase “Enter your data in RETIGO” (See Figure 6)

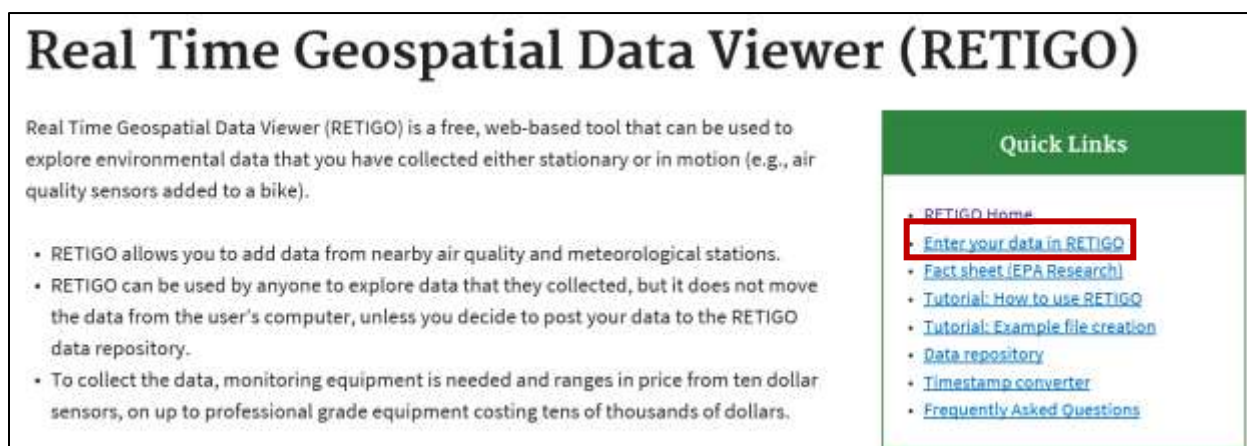


Figure 6 Screen shot from RETIGO Home page

9. You will see page for viewing a data file (see Figure 7. Click on “Choose File” and navigate to the folder on your computer where you saved the files and select the file that you wish to upload/view. For example: “2018_5_18_9-1-58.txt”
10. Once the file name appears in the place of the text “No file chosen”, then click “View” (see Figure 7).

View a data file

You may choose your own file to view, or pick one from the public data repository.

NOTE: Data files in the repository are **NOT QUALITY CHECKED** and are in no way endorsed or verified by the US Environmental Protection Agency. The repository is simply a service offered to RETIGO users to share data. The data in the repository is provided on an AS-IS basis.

* Your file: No file chosen

☐ Repository:

Figure 7 Screen shot of RETIGO Data Entry webpage

11. Next, the screen will display a map of your data. Below is an example of data taken at a school (Brookfield Elementary, Oakland, CA) in May 2018. In red, there are some questions for the students.

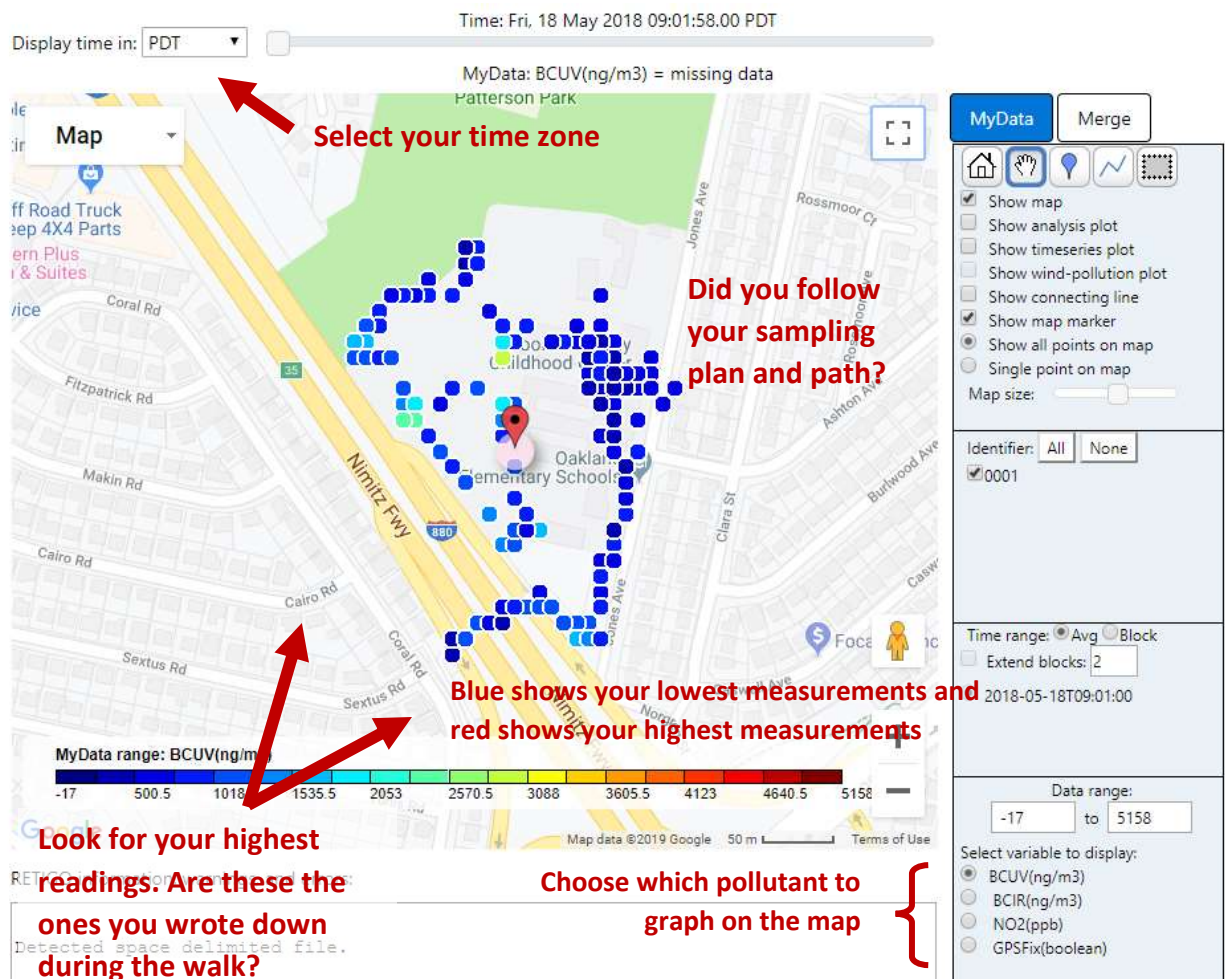


Figure 8. Example of RETIGO data.

Analyze and compare

- Take some time and explore the data. Choose different pollutants. Ask students why certain areas might be higher or lower in concentrations? Where are the sources of pollution? Which areas have higher pollution? Are those areas where people might be spending time? How do you think that affects their health?
- The maps from RETIGO can be used to look at the data that student took directly from the Briefcase/PAQS and compare that with the observations that they wrote down by hand looking at the screen of the PAQS.

LESSON #2: Our School, Our Community, Our Air!

TOPIC: Vegetative Barriers

NGSS STANDARDS

K-ESS3-3: Earth and Human Activity	Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.
K-ESS2-2: Earth's Systems	Construct an argument supported by evidence for how plants and animals (including humans) change the environment to meet their needs.
4-ESS3-2: Earth and Human Activity	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
5-ESS3-1: Earth and Human Activity	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
K-2-ETS-1-3: Engineering Design	Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.
K-2-ETS-3: Engineering Design	Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.

LESSON GOALS: Students will...

- Be able to explain the significance of vegetative barrier projects (*note that these lessons were created for a vegetative barrier project for a school, but can be adapted to other community spaces).
- Learn to use and read the sensors for future data collection.

KEY VOCABULARY: Vegetative Barriers; Pollution; Environmental Protection Agency

BACKGROUND FOR TEACHERS: It is important that students understand why the vegetative barrier project is important to their school and community. For this reason, identifying as a stakeholder in the project is going to be critical to students. A stakeholder is a person or group of people that have an interest or concern in a problem, like air pollution and its health effects. It can be students, teachers, parents, school administration, elected officials, or other local community members.

While student use of the sensors may be the more interactive component of a vegetative barriers project, students should consider the role of barriers and why it has an immediate impact on their health and their community. Barriers can help with air pollution, but also with the effects of noise. Vegetative barriers are a type of “urban green infrastructure.” Infrastructure is usually a word used for structures like road, bridges, and other things built by people. Green infrastructure is people using nature (like planting trees or saving wetlands) to solve the same problems. Instead of building a concrete wall to block air pollution or noise, trees and vegetation can create a buffer. Trees and vegetation can also help create shade and reduce temperatures (urban areas can be warmer because of the [heat island](#) effect), store carbon from the atmosphere, improve the safety and beauty of a community, among other environmental and public health benefits.

Art supplies and classroom notes are not included with these materials, as your notes will need to reflect your classroom needs. If you need additional resources to create your own unique instructional tools, please visit www.epa.gov for more information on various topics, including air quality. A student and parent information sheet are also available for the project, and is an effective tool for student and parent engagement.



IN CLASS ACTIVITY: Vegetative Barriers in Our Community: Past, Present, and Future

MATERIALS: Art Supplies (construction paper, cardstock, poster board, markers, crayons, etc.); Access to multimedia devices

TEACHER INSTRUCTIONS: This activity is design for schools or communities where there is an ongoing project or efforts to create a vegetative barrier (or perhaps other green infrastructure) at their school or nearby in their community (a park or other community space). Students will demonstrate their understanding of the vegetative barriers by creating a presentation designed to tell parents, the community, or other stakeholders about what the barrier is and why it is important to the school/neighborhood/community. How do they think the trees will help over time to improve the air quality in your community? How will cleaner air affect people’s health? Who will benefit the most? Are there certain people who spend more time in that area? Are

certain people more affected by air pollution than others? Presentation styles may vary among students, and can include (but are not limited to):

- Power Point or Prezi presentation
- Pamphlet or Informative Flyer
- Public service announcement (e.g. for radio)
- Storytelling or song (any type)
- Trifold or Poster
- Diorama
- Artwork, including murals
- Dramatic activity such as a skit or short film (e.g., live action or stop | start film)

Students should include information about the project's origin, the planting of the barriers, the sensors, and what they will be measuring. This can be completed as an individual or group activity and should take several days to complete.

Students from the upper grade levels may want to consult the resources below for additional background. The teacher can also use these sources for background material when discussing the project with students in the lower grade levels.

The resources below are specific to the Brookfield Elementary School Vegetative Barrier Study. Teachers are encouraged to identify links to other projects or efforts relevant to any local efforts in their communities.

<https://www.epa.gov/innovation/building-capacity-measure-air-pollution-mitigation-strategies-schools>

<https://www.eastbaytimes.com/2017/03/10/the-greening-of-brookfield-elementary-school/>

<https://oaklandnorth.net/2017/09/15/an-environmental-barrier-gives-students-at-one-oakland-school-a-chance-at-fresh-air/>

https://www.epa.gov/sites/production/files/2015-10/documents/ochp_2015_near_road_pollution_booklet_v16_508.pdf

Other information on vegetative barriers may be found through a variety of sources, including state or local governmental natural resources, environmental, and transportation agencies; U.S. Department of Agriculture Extension Services; U.S. Forestry Service; and, local universities with agricultural or urban planning or landscape programs.



IN CLASS ACTIVITY: Our Community's Green Barrier as it Grows

Upper grade level students can also include in their project a description of how they would like their school's or community's barrier to look in the *future* as it continues to grow. They can use the table in the EPA report (also shown below) to describe the physical characteristics of the barrier. How high, thick (or wide), and long should the barrier be? The table uses meters; the students can estimate using yards and feet instead.

Students in these grades will integrate math concepts such as area and volume to estimate the size of their barrier. See the "Vegetative Barrier Area and Volume" worksheet in the Supplemental Material. They can also use the map in the Supplemental Materials to estimate the measurements and draw the dimensions of the barrier. Student will estimate the length, width and height of what would make an effective barrier to stop the movement of pollution from the highway to their school. They will need to calculate the area for the barrier in two ways, one is if they are looking at the barrier as if it were a wall. That is, the length times the height. Ask the students why that would be important. Then, they will calculate the area for the barrier as if they were looking at it from above – that is, length times the width. Explain that this would be an important calculation to find the area on the ground. For example, if you needed to calculate the number of trees to plant. An extension could be estimating the number of trees that would be needed, if each tree, for example, requires 9 square feet of space to grow (3 ft. x 3 ft.).

Students can then describe what vegetation should be planted so that there are not holes or gaps in the barrier (porosity) that would let the air and pollution through. For porosity, students can also look at the pictures of good and bad vegetative barriers. Figure 9 shows good/effective barriers on the left, and ineffective barriers on the right.

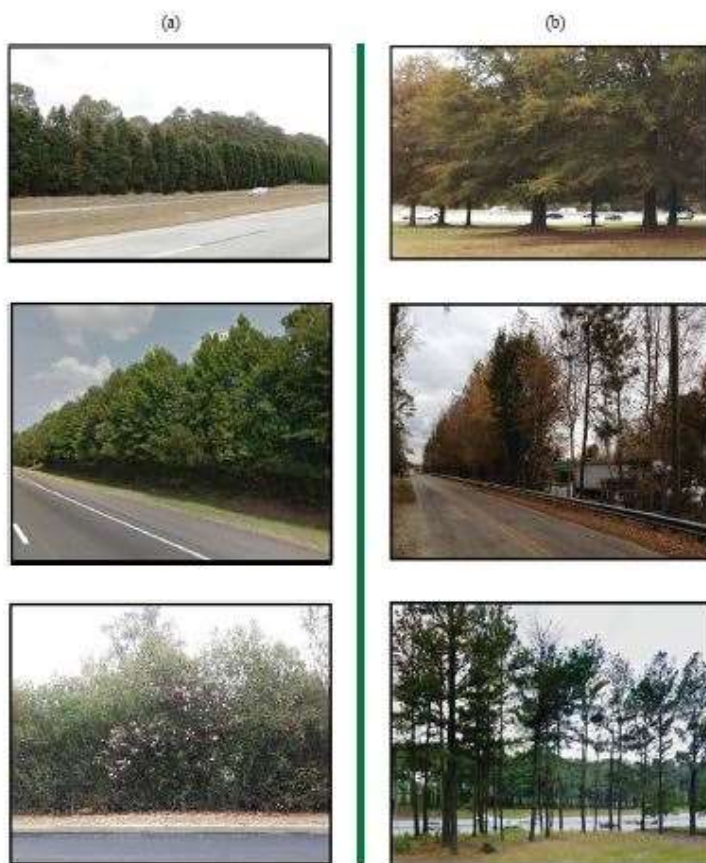


Figure 9. Examples of effective (a) and ineffective (b) roadside barriers. (Source: EPA)

For more information, teachers can download the report on roadside barriers from the EPA.
https://cfpub.epa.gov/si/si_public_file_download.cfm?p_download_id=528612&Lab=NRMRL

The Detroit-based Community Action to Promote Healthy Environments' resource guide also includes guidance on what types of tree species to use for vegetative buffers and barriers.
<http://caphedetroit.sph.umich.edu/buffers-and-barriers/>

ENRICHMENT/HOMEWORK: Host a School/Community Vegetative Barrier information booth at your next parent-teacher association/organization (PTA/PTO) meeting, school board meeting, or school wide event. Have students take responsibility for creating the visual aids and information flyers and have student volunteers interact with the parents/staff to inform them of the importance of the barrier project.

You may also create a classroom video of the students using the sensors and talking about the importance of the project to their environmental and personal health.



FIELD ACTIVITY: Taking Air Quality Data

MATERIALS: Mobile Sensor; Sensor Data Sheet; Data Collection Sampling Plan; Map of School

TEACHER INSTRUCTIONS:

This field activity uses the same sampling and data collection approach used in Lesson #1. This field activity focuses on vegetative barriers.

In small groups, have students work together to create a sampling plan of three to four locations surrounding the vegetative barrier which they would like to collect data. **Teachers can keep the sampling plans to maintain consistency of where samples are taken.** Explain that readings around the barrier may vary depending on the amount of vegetative growth. Have students look at locations that are parallel and perpendicular to the barrier. Are these measurements different than those right beside the barrier?

Discuss with students how they think this information might be different if they took the data next week, two months from now, six months from now considering growth of vegetation. Discuss how the growth of the barrier should impact the measurements and factors which might excel or slow down barrier growth (weather issues, temperature, other environmental conditions, etc.).

ENRICHMENT/HOMEWORK: If possible, have students take measurements with the PAQS (briefcase) at the stationary sensor in the beginning, middle, and end of the day. Teachers may want to compare the PAQS data with the SPAQ (birdhouse) data. Discuss potential reading fluctuations due to temperature, sunlight, and traffic changes. Consistency in data collection is important. Make sure that the students are taking consistent notes for all of the observations.

**Note: To access SPAQ data, teachers will need to be trained in the downloading and use of the data from the SPAQ sensors. This material is not included in these lessons. **

LESSON #3: How Sensors Work

TOPIC: Sensors/Data Collection

NGSS STANDARDS

K-ESS3-3: Earth and Human Activity	Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.
K-ESS2-2: Earth's Systems	Construct an argument supported by evidence for how plants and animals (including humans) change the environment to meet their needs.
4-ESS3-2: Earth and Human Activity	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
5-ESS3-1: Earth and Human Activity	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
K-2-ETS-1-3: Engineering Design	Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.
K-2-ETS-3: Engineering Design	Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.
3-5-ETS-1-3: Engineering Design	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.

LESSON GOALS: Students will...

- Explain how sensors assist in gathering data

- Demonstrate mastery in the use of air quality sensors

KEY VOCABULARY: Sensor; Battery; Microprocessor; Sensor Package; Solar Panel; Power; Component; Data

BACKGROUND FOR TEACHERS:

Using sensors will likely be a new concept for students. For this lesson, the in-class activity will require purchasing or borrowing Do-It-Yourself (DIY) sensor kits for students to build and test for themselves. Please note the Venn Diagram activity does not require the use of DIY sensors. A traditional Venn Diagram (as opposed to Triple Venn Diagram) can be used if only looking at the birdhouse and briefcase sensors.

DIY Sensors, while “low-tech,” are quite sensitive to picking up on changes in air quality. Comparing these homemade sensors to the “high-tech” EPA sensors is a good way to demonstrate to students the range of tools scientists use. You can even mention that there are even more advanced instruments used by scientists, but those are often large and expensive.

For the field activity, your students should be able to observe notable changes in the air quality at different times of the day. There are many variables which could contribute to changes in measurement, including (but not limited to) temperature, sun exposure, and traffic conditions.

Included in this lesson plan is a sensor recording sheet. **Classroom notes are not included with these materials, as your notes will need to reflect your classroom needs. If you need additional resources to create your own unique instructional tools, please visit www.epa.gov for more information on various topics, including air quality.**



IN CLASS ACTIVITY: DIY Sensors

MATERIALS: DIY Sensor Kit

NOTE: This is not a lesson on how to make a DIY sensor. This activity will describe how to make comparisons between the DIY Sensor Kits and the PAQS sensor.

If you’d like to make the DIY sensor, there are a number of resources on the internet.

For this activity, we suggest using the Particulate Matter (PM) Air Sensor activity developed by EPA. A full set of instruction and materials are available at: <https://www.epa.gov/air-research/air-quality-and-energy-choice-stem-activities-educators>

TEACHER INSTRUCTIONS:

Use the instructions on the DIY Reference Sheet to guide students through the construction of their very own air quality sensor.

For many students, this will be the first time they have engineered their own versions of items they have seen used in science. Allow the students (working in small groups) to try different strategies and question them about how they are creating their sensors. Once the group has decided they are confident their sensor will work, have them test it out by exposing the sensor to “pollution.” One can create air “pollution” for the monitors by rubbing two pieces of paper together, rubbing hands together, or tearing newspaper into pieces. The sensor will pick up those particles. Allow students to take their monitors outside and around the school to see if their sensor picks up higher levels of air pollution in some places than others.



FIELD ACTIVITY: Using Sensors for Data

MATERIALS: Paper to take notes, large paper for Venn Diagram

TEACHER INSTRUCTIONS:

REMINDER: Students should be supervised at all times when using sensors.

Students may work in pairs or small groups as necessary. This lesson is designed to introduce students to the components of different sensors and ways the sensors are combined into sensor packages.

For All Sensors:

- Identify the following components and how they are combined to make the sensor packages:
 - Battery/Power Source
 - Hint: sensors run off battery, there are additional batteries for the screen on the briefcase, solar power is added for the birdhouse)
 - Sensor
 - Hint: there are BC and NO₂ sensors for both the birdhouse and briefcase, PM for the DIY kit)
 - Computers/Microprocessors
 - Hint: There are no microprocessors for the birdhouse; the briefcase has two microprocessors (one for collecting data from the sensors, one on the back of the screen for displaying the data); and the DIY kit all connects to a microprocessor board.
 - Data Display
 - Hint: the briefcase has a screen that gives all of the data; the sensors in the birdhouse do not have a screen, the NO₂ sensor has small data display and there are indication lights on BC sensor; the DIY sensor has LED lights to show levels of air pollution, but no data readings unless connected to a computer.

For the Stationary Sensor (Birdhouse):

- Why do you think the engineers who designed our stationary sensor made it look like a birdhouse?
- Take out the sensors and read the label to see what pollutant they measure (do you see black carbon or BC, NO₂ on the label)?
- Why do you think it is good for a sensor to stay in one place?
- Why are there solar panels to help charge the battery? Do you think this was a good idea?
- How does wind speed have anything to do with air pollution?
- Is it easy or hard to take out the sensors, could more sensors be added?



For the Mobile Sensor (Briefcase):



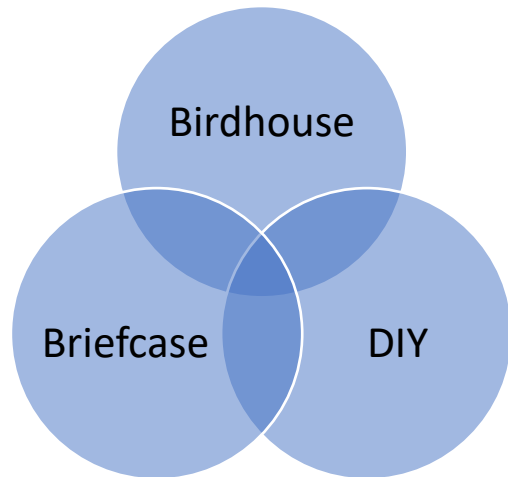
- Why is it important to have a sensor package that can move around?
- What do you notice about the inside of the briefcase that is different than the birdhouse?
- Look for the battery, where is that and how big is it?
- Look for where the air comes into the BC sensor, can you find the inlet?
- Do you hear a fan run when you turn on the power?
- If the two sensor packages (briefcase and birdhouse) measure the same information, why do you think they look so different?

For the DIY Sensor (if you choose to use one)

- How does a DIY sensor work differently than the sensors we have in class?
- Do you think the DIY sensor is more accurate or less accurate than the other sensors? Why?
- When might you use a DIY sensor instead of one of the more advanced sensors?

Create a Venn Diagram to compare and contrast the sensors packages. How are they the same? How are they different? If using the DIY sensors as well, create a Triple Venn Diagram. Some questions to guide students in comparing the sensor packages include (but are not limited to):

- Which pollutants are measured? (BC, NO₂, PM)
- Which sensors can be moved around to different places (mobile)?
- Which sensors are made to stay in one place for a while (stationary)?
- How many sensors do they have inside? (1 or 2)
- Do they have a small microprocessor (like an Arduino board) connected to the sensors?
- Are the sensors inside the packages large or small? (can they fit in your hand)
- Which sensor packages (birdhouse, briefcase, DIY) are heavy or light? (can the students carry them easily)
- Do the sensor packages have a display to show you the amount of pollution right away, or do you have to connect to a computer to see the data?
- Do they have a battery? Is the battery big or small?
- How do they recharge the battery? (need to plug in to the wall, solar panel)



LESSON #4: What's in the Air?

(This lesson can also be taught as a standalone lesson or for background before Lesson #1)

TOPIC: Air Quality

NGSS STANDARDS

K-ESS3-3: Earth and Human Activity	Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.
K-ESS2-2: Earth's Systems	Construct an argument supported by evidence for how plants and animals (including humans) change the environment to meet their needs.
4-ESS3-2: Earth and Human Activity	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
5-ESS3-1: Earth and Human Activity	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
K-2-ETS-1-3: Engineering Design	Ask questions, make observations, and gather information about a situation people want to change to define a simple problem that can be solved through the development of a new or improved object or tool.
K-2-ETS-3: Engineering Design	Analyze data from tests of two objects designed to solve the same problem to compare the strengths and weaknesses of how each performs.
3-5-ETS-1-3: Engineering Design	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.

LESSON GOALS: Students will...

- Demonstrate understanding of the Air Quality Index.
- Describe how air quality can change over periods of time.

KEY VOCABULARY: Air Quality Index (AQI); Pollutant; Particle(s)

BACKGROUND FOR TEACHERS:

When discussing human health and the environment, air quality is an important topic for students to understand. Regardless of a students' background, they are all affected by the air they breathe. For some students, especially those living with asthma or those who play outdoor sports, this topic may seem particularly relevant.

Remind students that there are many forms of air pollution – naturally occurring and man-made sources. When discussing this topic, creating and describing pollution sources may be helpful in showing students common air pollution sources. Students can also consider how air quality may differ inside (indoor air) and outdoors (ambient air quality). Many students may not include sources such as wildfires or fires from “prescribed burns,” which are burns that are planned and controlled and used for agricultural and forest management. You can then use the natural pollution sources and compare them to the man-made sources. Ask students which types of pollution we can control and use those sources to create your classroom lesson.

Included in this lesson plan are: blank maps for in class-coloring activity and a Sensor Data Sheet. **Classroom notes are not included with these materials, as your notes will need to reflect your classroom needs. If you need additional resources to create your own unique instructional tools, please visit www.epa.gov for more information on various topics, including air quality.**

ADDRESSING MISCONCEPTIONS:

At the beginning of this lesson, ask students, “What is in the air we breathe?” It is likely your students will respond with a common answer, “Oxygen.” The idea that the air around them is made up of just oxygen is a common misconception for students. To teach air quality in a way that elementary students will understand, we must first address this misconception and have students understand that there are a lot of invisible particles in the air that we breathe every day. It is also critical to discuss the fact that some of the things in our air are called pollutants and can be harmful to the environment and human health. This misconception should be addressed during the In-Class Activity portion of this lesson.

Another misconception many students have is that air quality in a location is static. It is important for students to understand that air quality in a location changes throughout the day, based on many variables such as: time of day, temperature, wind speed and direction, vehicle

traffic, industry, etc. To demonstrate this to students, it is best to use sensors to collect and examine data. This misconception will be addressed during the Field Activity portion of this lesson.



IN CLASS ACTIVITY: Air Quality At-A-Glance

MATERIALS: Internet Activated Devices; Map of California; Map of the United States; Map of the Globe



Figure 10. Air Quality Index (AQI) map showing California.

AQI color and label the information about their city's current conditions. Then have them color in the rest of the map (labeling major cities) to show the current air quality for the state. The same can be done with maps for the national and international air quality reports. Discuss reasons why the air quality may be higher in some areas, including those with major highways or cities with heavy industrial facilities.

ENRICHMENT/HOMEWORK: Give students a blank copy of the California, Michigan (included in Supplemental Materials), or their own state map and have them color and label areas during a date and time different than their original data collection. Then, have students fill out the Air Quality Enrichment Sheet. As a class, discuss the data the students collected and why their measurements may have differed.

TEACHER INSTRUCTIONS: Allow students (individually or in pairs) to access the airnow.gov website and explore the available maps. After students have had the opportunity to explore a couple of locations, have them select California and discuss the current air quality measurements across the state. Do they notice any patterns? Are there any areas where the air quality is much better or worse than others? Have the students select a specific city in California. Does any of this information surprise them?

Provide students with the blank map of California (Supplemental Materials) and label with a star* the location of their town. They should color the area with the corresponding

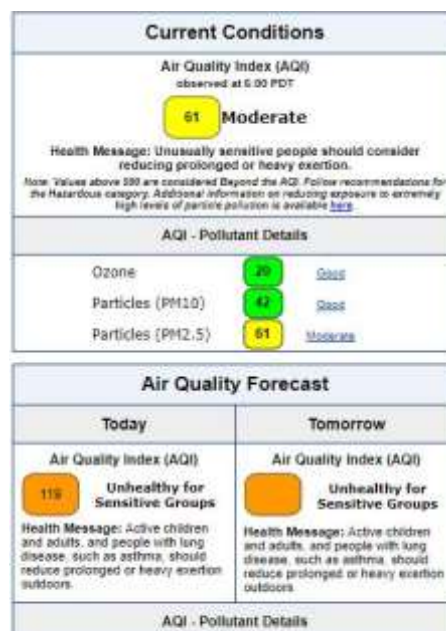


Figure 11. Example of AQI information for current conditions and forecast.

You may also print out maps of different states and assign one (or more) to each student. Then, cut out the states and assemble them together in the form of an air quality map. It is also important for students to think about how air pollution might travel. Pollution won't stay in one state, or even a country!



FIELD ACTIVITY: Comparing Air Quality Measurements

MATERIALS: Mobile Sensor; Sensor Data Sheet

TEACHER INSTRUCTIONS:

REMINDER: Students should be supervised at all times when using sensors.

This field activity uses the same general sampling and data collection approach used in Lesson #1. This field activity focuses on indoor/outdoor air quality.

Provide students with a sensor reading recording sheet. Students may work in pairs or small groups as necessary.

Using the mobile sensor, have students create a sampling plan of indoor and outdoor locations where they can collect data. Over the course of five days, have students collect data at three indoor and three outdoor locations. They should collect from the same places each day. Discuss with students that the AQI is used to measure outdoor ambient air quality. Ask them if they were surprised by any of their findings when reviewing the indoor or outdoor data. Can students think of reasons why some of the data may have been higher or lower than they expected?

Using graph paper, have students create a graph where they will record their data. After five days, have students look at the changes over time.

- What could have caused some of the differences in the data?
- Why did they choose to label their axes as they did?
- Did their values on the y-axis ever need to be changed?

ENRICHMENT/HOMEWORK:

If possible, teachers should take measurements at the stationary sensor in the beginning, middle, and end of the day. Discuss with students potential reading fluctuations due to temperature/weather, sunlight, and traffic changes.

Students may be surprised that the air indoors can be as polluted as the air outdoors. Were there activities that they noted going on indoors that may have contributed to the inside measurements? Are there things going on outside that might be adding to the pollution inside? Have students research ways to improve indoor air quality in times of poor outdoor air episodes. Have students identify ways to reduce or control pollutants indoors. Have students upload the PAQS data into RETIGO and look for areas in which the data was higher than average. What might have caused these numbers to spike?

LESSON #5: Emissions Issues

TOPIC: Emissions and Air Pollutants, with a focus on Black Carbon

NGSS STANDARDS

K-ESS3-3: Earth and Human Activity	Communicate solutions that will reduce the impact of humans on the land, water, air, and/or other living things in the local environment.
K-ESS2-2: Earth's Systems	Construct an argument supported by evidence for how plants and animals (including humans) change the environment to meet their needs.
3-ESS3-1: Earth and Human Activity	Make a claim about the merit of a design solution that reduced the impacts of weather related hazard.
4-ESS3-2: Earth and Human Activity	Generate and compare multiple solutions to reduce the impacts of natural Earth processes on humans.
5-ESS3-1: Earth and Human Activity	Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

LESSON GOALS: The student will...

- Describe what black carbon is and how it is emitted.
- Discuss long-term effects of black carbon being released into the atmosphere, including health, climate, and other environmental impacts.

KEY VOCABULARY: Black Carbon; Particulate Matter (PM); Emissions; Fossil Fuels; Diesel; Heavy Duty Vehicles; Light Duty Vehicles; Gasoline

BACKGROUND FOR TEACHERS:

Many conversations around black carbon focus on two areas: vehicle emissions, (particularly diesel vehicles) and burning of biomass (plant matter) such as during wildfires. It is important to note for students that black carbon is produced from fossil fuels like diesel and ask them to come up with sources. What types of vehicles use diesel? What would cause burning of biomass (or plant material)?

An overview of black carbon and its effects can be found here.

<https://www3.epa.gov/airquality/blackcarbon/basic.html>

<https://www3.epa.gov/airquality/blackcarbon/effects.html>

Black carbon can be dangerous to human health as well as the environment, which is one of the primary reasons the vegetative barrier project began. Depending on the grade level of the students, this introduction to black carbon is a great way to start a discussion on climate change and how human activity impacts the environment at a global level.

Classroom notes are not included with these materials, as your notes will need to reflect your classroom needs. If you need additional resources to create your own unique instructional tools, please visit www.epa.gov for more information on various topics, including air quality.

ADDRESSING MISCONCEPTIONS:

Students may be familiar with seeing tailpipe emissions as black plumes of smoke coming from commercial vehicles or diesel trucks. What many students don't realize is that the majority of vehicles on the road produce tailpipe **emissions**, whether visible or not. **Black carbon** is the sooty material which is produced from the burning of fuels such as **diesel**. Students should understand that when **fossil fuels** are burned, black carbon emissions are released into the atmosphere. In the U.S., most black carbon emissions come from diesel motors and engines. Some black carbon emissions come from burning of other fossil fuels.



Figure 12. Size comparisons for PM particles (Source: EPA)

Black carbon is an important share of **fine particulate matter** and is associated with the health effects that scientists have studied for fine particulate matter (also known as PM_{2.5} because the particles are smaller than 2.5 micrometers). www.epa.gov/pm-pollution/particulate-matter-pm-basics.

Other pollutants are also released during fossil fuel burning. This leads not only to immediate

health issues for sensitive populations, but to long term health effects for those who are regularly exposed.

Another misconception that students often have is that when the “smoke” they see disappears, it is no longer in the air. Children are often unaware that there are invisible particles diluted in the air they breathe that can cause damage to the environment or human health. This misconception will be addressed in the In-Class Activity for this lesson.



IN CLASS ACTIVITY: Emissions, Our Health, and the Environment

MATERIALS: Internet Activated Devices; Art Supplies

TEACHER INSTRUCTIONS: This activity could be done in the context of weather and climate as well as human health. Provide students with art materials and have them draw a picture depicting a source of black carbon emissions. Sources can include diesel vehicles such as some cars and heavy-duty trucks. Where would they find a lot of diesel vehicles – generally larger freight trucks? Maybe the school buses are diesel? Coal-fired power plants are another source of black carbon. Can they see one or find one on a map? In addition to fossil fuel use, black carbon can also come from burning biomass (plant materials), which can include wildfires. Students may consider every day examples such as using a grill or fire pit. In other parts of the world, biomass like wood and charcoal may also be used for daily cooking needs.

They can pick a pollution source and pick either the U.S. or another country. You can assign students a scenario to draw or allow them to choose from the ones discussed in class. In their drawing, have them label the source and include information about who might be affected by the emissions. For instance, in parts of the U.S. or in other parts of the world, which family members would typically be in the cooking areas when people are cooking over woodstoves? What about near a fireplace? Students can consider both outdoor and indoor sources. If they are drawing truck emissions from a busy highway, what is nearby? Are there businesses, homes, schools, churches, or parks? Who would be here and do they spend a lot of time here? Would they be here when there are a lot of emissions? (For example, if the students are drawing a school near a highway, the students will generally be at school during the weekday when traffic may be heaviest)

Engage students in discussions about those individuals who might be considered **sensitive** to air quality changes. Students can use this guide to air quality and health for more information: www.epa.gov/airnow/aqi_brochure_02_14.pdf.

Have students review the differences regarding which groups are most at risk for different pollutants, such as ozone, carbon monoxide, and particle pollution. They should focus on **particle pollution**, also known as fine particulate matter or PM_{2.5}. Black carbon is an important share of **fine particulate matter** and leads to the many health effects that scientists have studied for fine particulate matter.

ENRICHMENT/HOMEWORK:

Explain to students that there are many things they cannot see that impact them. For instance, they cannot see the flu virus, but they know when they are exposed to it! Exposure to black carbon, as well as other air pollutants, does not always make someone feel sick right away, but instead, may have long lasting effects over time.

Have students research ways to lower their risk of exposure to air pollutants. Students can then create a “Healthy Me!” poster similar to other medical-themed posters they may see in their school. You can hang these posters up around the school and even ask administration to make announcements about the air quality and ways to stay healthy. You can even encourage your school to participate in EPA’s Air Quality Flag Program, which alerts your community to the local air quality forecast and helps them take actions to protect people’s health, including those with asthma. Visit https://airnow.gov/index.cfm?action=flag_program.index for more information.



FIELD ACTIVITY: Graphing Black Carbon

MATERIALS: Mobile Sensor; Sensor Data Sheet

TEACHER INSTRUCTIONS:

REMINDER: Students should be supervised at all times when using sensors. Students and teachers, in particular those who may be more sensitive to air pollution, particularly children with asthma, should take additional precautions if the pollution levels are high. This includes paying attention to any symptoms such as coughing, chest tightness, or wheezing when breathing. Ensure that any inhalers or other personal protection equipment, such as masks, are on hand.

Additional information regarding indoor air quality and management of asthma in schools is available here:

www.epa.gov/iaq-schools

www.epa.gov/iaq-schools/managing-asthma-school-environment

This field activity may be best for small groups such as before- or after-school clubs. Before and after school groups may be able to allow for measurements to be taken while buses and other vehicles are idling (running engines while not moving) at the beginning and end of the day. This activity may be modified for use with larger groups.

Provide students with a sensor reading recording sheet. Students may work in pairs or small groups as necessary.

Using the mobile sensor, have students create a sampling plan of indoor and outdoor locations where they can collect data specific to **black carbon**. Over the course of five days, have students safely collect data near carpool lanes, bus parking, and roadways. Students shouldn't collect data directly behind the bus exhaust, but instead be on the sidewalk in the general vicinity. Explain to students that BC emissions from heavy duty vehicles (large trucks, buses, and other large vehicles) will be higher than emissions from light duty vehicles (passenger vehicles such as cars, minivans, and SUVs). This is due to the fact that most heavy-duty vehicles rely on diesel fuel, whereas most light-duty vehicles rely on gasoline.

Students should collect from the same places each day. Can students think of reasons why some of the data may have been higher or lower than they expected for the different locations?

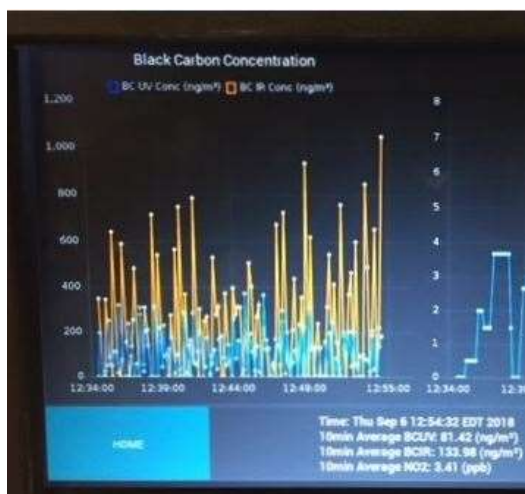


Figure 13. Screen view of Briefcase with Black Carbon readings

Using graph paper, have students create a graph where they will record their data. After five days, have students look at the changes over time. For this activity, only record **IR Black Carbon** data from the briefcase sensor.

- What could have caused some of the differences in the data?
- Why did they choose to label their axes as they did?
- Did their values on the y-axis ever need to be changed?

SUPPLEMENTAL MATERIALS

Group: _____

Date: _____

Sensors Data Sheet

Time (5 minutes)	Location (Physical Description)	GPS Location (Latitude & Longitude)	BCIR Highest & Lowest Measurements	BCUV Highest & Lowest Measurements	NO₂ Highest and Lowest Measurements	Ten Minute Averages	Observations
		Lat: Long:	High: Low:	High: Low:	High: Low:	BCIR: BCIV: NO ₂ :	
		Lat: Long:	High: Low:	High: Low:	High: Low:	BCIR: BCIV: NO ₂ :	
		Lat: Long:	High: Low:	High: Low:	High: Low:	BCIR: BCIV: NO ₂ :	
		Lat: Long:	High: Low:	High: Low:	High: Low:	BCIR: BCIV: NO ₂ :	
		Lat: Long:	High: Low:	High: Low:	High: Low:	BCIR: BCIV: NO ₂ :	

Group: _____

Date: _____

Observation Data Sheet

Station Name & GPS Location (Latitude and Longitude)	Is the vegetative barrier visible? How does it look?	Weather Observations (Conditions, Temperature, Wind Speed/Direction, etc.)	Cloud Cover and Types	Do I smell/see any smoke, soot, or steam? Any other odors/smells?	Do I see/hear traffic?	Other Area Observations

Group: _____

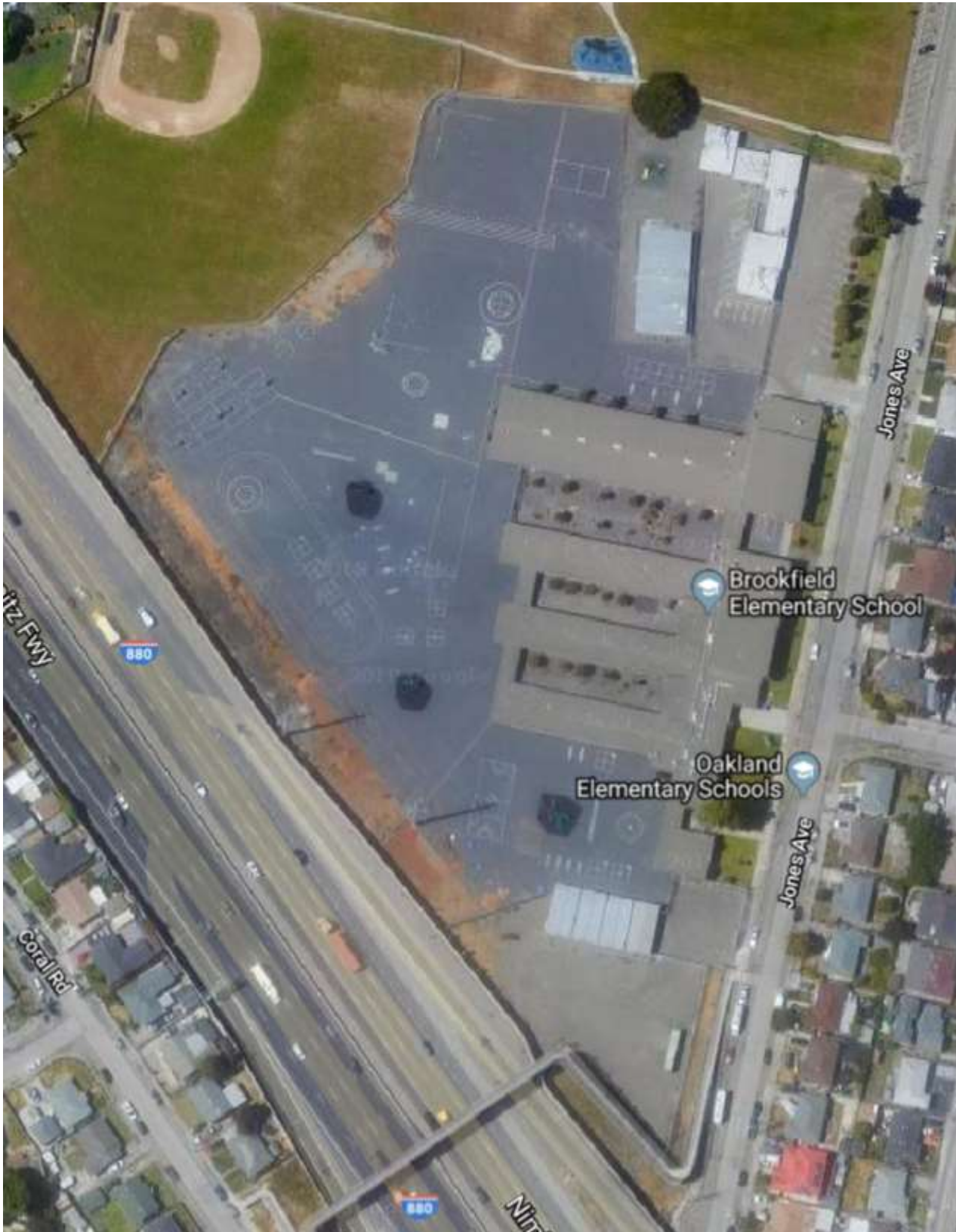
Date: _____

Data Collection Sampling Plan

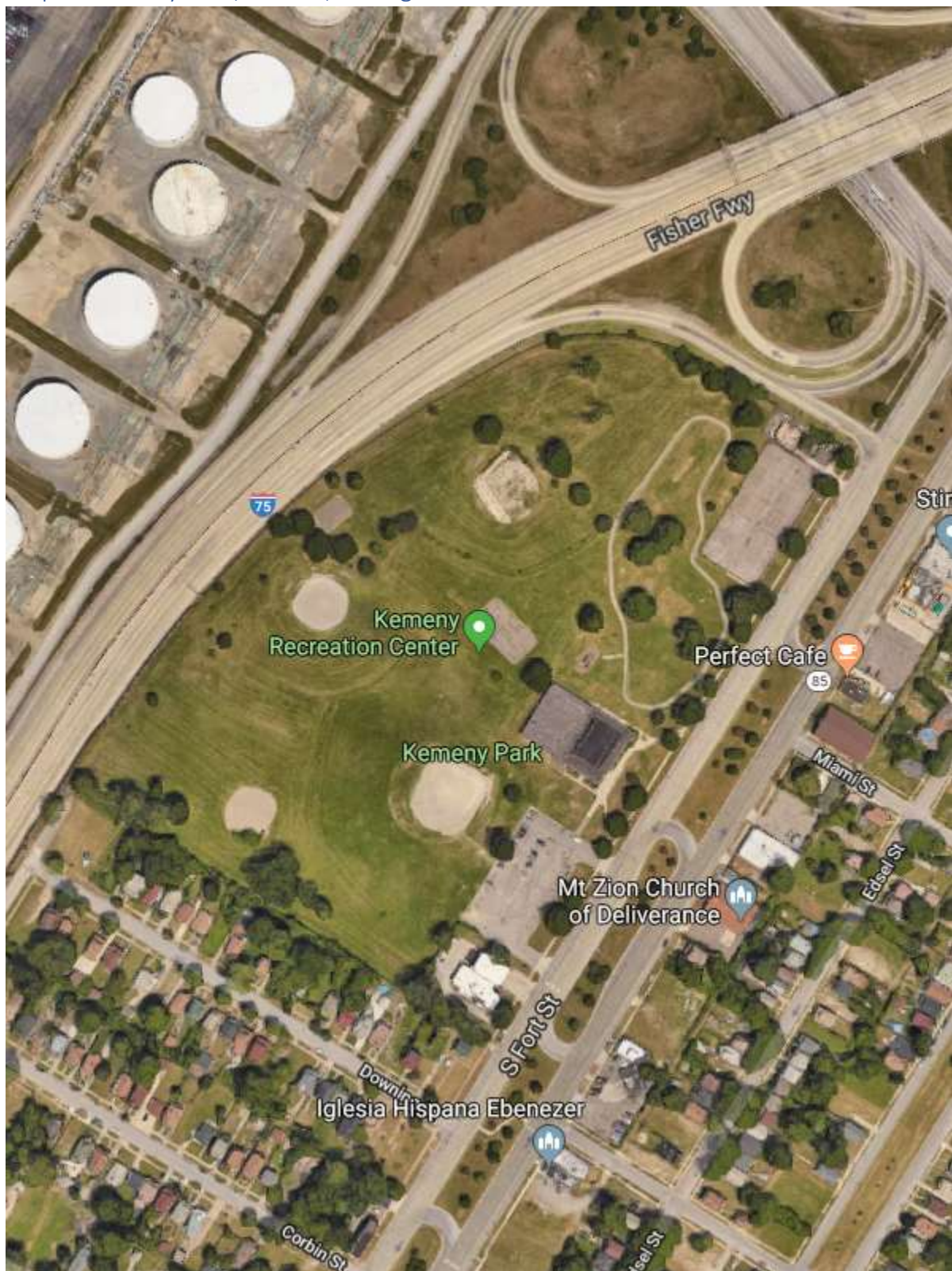
Names of Group Members:

Sampling Point	Data Collector at Sampling Point
<i>Example: Next to Carpool Lane</i>	<i>Alex R.</i>

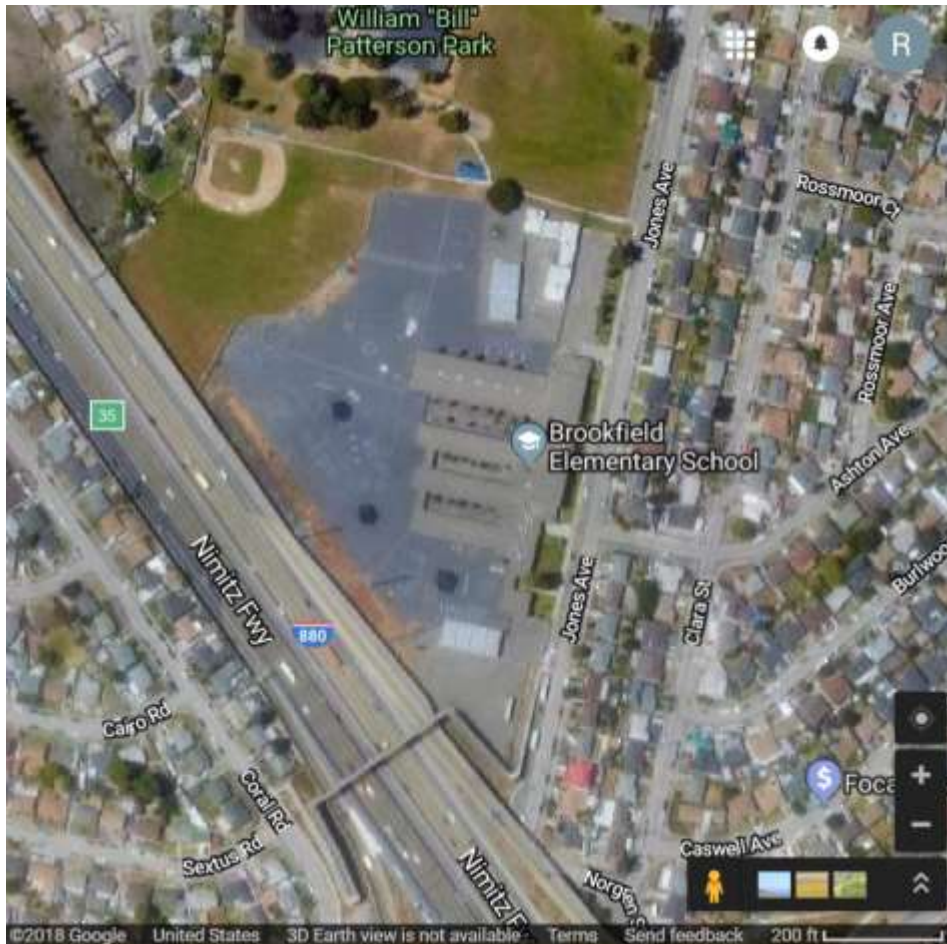
Map of Brookfield Elementary, Oakland, California



Map of Kemeny Park, Detroit, Michigan



Brookfield's Barrier as it Grows: Area and Volume



Draw the vegetative barrier on the map to block any pollution from the freeway. Make sure it's long enough and high enough. How wide would it be?

●———● This line equals 200 ft. on the map.

Length of the barrier: _____ ft.

Height of the barrier: _____ ft.

Width of the barrier: _____ ft.

Area of the barrier if you are standing and looking at it: _____ ft²

Area of the barrier if you are looking at it from above: _____ ft²

Volume of the barrier: _____ ft³

Describe any other characteristics of your vegetative barrier. What type of trees and bushes would you use? What would work best for California's weather?

Characteristics of Barriers

Barrier Characteristic	Recommendation	Description
<i>Physical Characteristics</i>		
Height	5 meters or higher (or extend 1+ meter above an existing solid barrier)	The higher the vegetative barrier, the greater the pollutant reductions. A minimum of 5 meters should provide enough height to be above typical emission elevations for vehicles on the road. However, heights of 10 meters or more would likely provide additional pollutant reductions.
Thickness	10 meters or more	The thicker the vegetative barrier, the greater the pollutant reductions. A minimum thickness of 10 meters should provide enough of a barrier to remove particulate and enhance dispersion. However, gaps in the barrier should be avoided. Multiple rows of different types of vegetation (e.g. bushes, shrubs, trees) should be considered for maximum coverage and pollutant removal during all stages of the barrier.
Porosity	0.5 to 0.9	Porosity should not be too high to allow pollutants to easily pass through the barrier or cause wind stagnation. As the porosity gets lower, the vegetation barrier will perform similarly to a solid barrier, which may limit the amount of particulate removal since air is forced up and around the plants.
Length	50 meters or more beyond area of concern	Extending the barrier beyond the area of concern protects against pollutant meandering around edges. May also consider constructing the barrier perpendicular from the road depending on land availability.

*Students can substitute yards for meters.

California Map



Michigan Map



U.S Map



World Map

