The Power of Plants! How Vegetation Can Help Protect Us from Air Pollution

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Air sensors can help make invisible air pollution visible! This hands-on, interactive lesson plan is designed to give users an introduction to air sensors, common sources of particulate matter (PM), and the health effects of breathing in PM. Users will also learn about vegetation and how certain types can be used as a barrier against PM. Using a handheld AirBeam2 PM sensor, users will go outside and measure PM in the community near a vegetative barrier (if one exists)! After collecting data, users will learn how to interpret the PM measurements and based on the results, learn how an existing vegetative barrier works, or suggest a location where a vegetative barrier in the community might be effective.

This lesson plan includes:

- Lesson Plan aligned with Next Generation Science Standards (NGSS)
- Extension Activity
- Introductory Presentation Slides
- Data Collection Worksheet
- Worksheet Answer Key

Additional resources to support this lesson plan can be found on the Air Sensor Toolbox Educational Resources page at https://www.epa.gov/air-sensor-toolbox/educational-resources-related-air-sensor-technology.

In addition to a resource guide and frequently asked questions, other resources give user instructions for the AirBeam2 sensor and provide more background information:

1. AirBeam2 Quick Start Guide and Presentation Slides
   https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=CEMM&dirEntryId=350603
2. AirBeam 2 Instructional Video
   https://www.youtube.com/watch?v=JCXVFEsm6o8
3. Air Quality 101: A Background on Air Pollution (Presentation Slides)
   https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=CEMM&dirEntryId=349514
4. Advanced Topics in Using Sensors to Measure Air Quality (Presentation Slides)
   https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=CEMM&dirEntryId=350602

These materials are meant to be accessible and adaptable. Users may use these suggested activities as a starting point to design and conduct experiments of their own. These materials target a 6th grade level; however, they may be adapted as necessary for younger or older audiences. Although the materials mention use of the AirBeam2 PM sensor, the lesson can be conducted with other PM sensors. If you create adapted materials that you wish to share with others, you may contact clements.andrea@epa.gov.

These materials were originally developed to support the Air Sensor Loan Programs in EPA Region 5. We would specifically like to recognize the following individuals, who worked to establish the loan programs, contributed to developing the concept for the lesson plan, and reviewed the materials.

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Lesson Overview

Alignment with Next Generation Science Standards

Middle School Standards	
MS-LS2	**Ecosystems: Interactions, Energy, and Dynamics**
MS-LS2-3	Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.
MS-LS2-4	Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations.
MS-LS2-5	Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
MS-ESS3	**Earth and Human Activity**
MS-ESS3-3	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ETS1	**Engineering Design**
MS-ETS1-1	Define the criteria and constraints for 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.
MS-ETS1-3	Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.
MS-ETS1-4	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.

High School Standards	
HS-LS2	**Ecosystems: Interactions, Energy, and Dynamics**
HS-LS2-7	Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
HS-ESS3	**Earth and Human Activity**
HS-ESS3-4	Evaluate or refine a technological solution that reduces impacts on human activities on natural systems.
HS-ETS1	**Engineering Design**
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.
HS-ETS1-3	Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics as well as possible social, cultural, and environmental impacts.

Cautions and Safety Considerations

As you work through the tasks in this activity, please keep these cautions and considerations in mind:

Safety Considerations

- **Minors should be accompanied by a guardian or parent when doing this activity.**
- **Wear bright clothing or a reflective safety vest when conducting air quality measurements near roads.**
- **Please obey caution signs posted near restricted areas (for example, construction areas, industrial areas, train tracks, or others). Do not sample in active construction areas or on train tracks.**
- **If walking along roads, please use sidewalks and follow common safety practices.**
- **Use caution while walking around with the AirBeam2 and phone to avoid tripping or colliding with others.**
- **Use caution in the rain–if it is raining hard, it may be safer to wait until after the rain slows down or has stopped to go out and take your measurements.**
- **The AirBeam2 is water-resistant, not waterproof–make sure to protect the sensor in the rain by using an umbrella.**
- **Make sure your AirCasting session name is descriptive and appropriate! The AirCasting sessions you record will be online and visible to the entire AirCasting community.**
- **If you would like to use the belt clip to carry the AirBeam2, use the screw provided to attach the belt clip to the top of the sensor. Using a different screw could puncture the battery and cause a fire. For help, consult your instructor or the Quick Start Guide.**

About This Lesson

In this activity, you will learn about common sources of particulate matter (PM) and the health effects of breathing in PM. You will also learn about vegetation and how certain types can be used as a barrier against PM. Using a handheld AirBeam2 PM sensor, you will go outside and measure PM in your community near a vegetative barrier (if one exists)! After collecting data, you will learn how to interpret your PM measurements and, based on your results, asked to suggest a location where a vegetative barrier in your community might be effective.

Before starting the activity, review the following background materials and resources on the Air Sensor Toolbox website (www.epa.gov/air-sensor-toolbox):

1. **Review the AQ101 Presentation.** This presentation provides background information on PM, including: What is PM? Where does it come from? Why should you care about PM?
2. **Read the introductory material or attend an instructor-led presentation on the introductory material**. The introductory material for this activity (The Power of Plants! - Presentation) will teach you about PM and common sources of outdoor PM.
3. **Review the Quick Start Guide or attend an instructor-led presentation on the Quick Start Guide.** The Quick Start Guide will teach you how to use the handheld AirBeam2 PM sensor.
4. **View the AirBeam2 Instructional Video**. This walks you through how to set up your AirBeam2, start a measurement session, and view your data. https://youtu.be/JCXVFEsm6o8

> **Important Note**
>
> Realize that if you use the PM sensor to take measurements, there may be different results based on what source you are measuring and for how long.
>
> This activity is merely a tool to help you realize how PM can vary at locations with and without a vegetative barrier.

Learning Objectives

In this activity, participants will go outside and measure particulate matter (PM) near a vegetative barrier in their community or near their home or school. Participants will learn about:

- Sources of particle pollution
- The benefits of vegetation
- How vegetation can serve as a barrier to block pollution
- The characteristics of an effective vegetative barrier
- How to use the handheld AirBeam2 sensor
- How to interpret the measurements collected by the AirBeam2

Participants will use their observations to suggest a location where a vegetative barrier might be effective.

Documents Associated with This Activity

- "**The Power of Plants! How Vegetation Can Help Protect Us from Air Pollution**" (this document)- contains introductory information on the activity, background information, step-by-step instructions, and questions to help you make sense of your results.
- **"The Power of Plants! - Data Collection Worksheet"** provides an organized place to write answers to the questions asked in this activity and take notes.
  - If you are performing this activity under the guidance of an instructor, the data collection worksheet will help you in group discussions, and you may need to turn it in (ask your instructor for more information).
  - If you are performing this activity individually after having borrowed the materials, you can use the Data Collection Worksheet to organize your observations and notes, but you will not need to turn it in to anyone.
- **"The Power of Plants! – Instructor Answer Key"** provides answers to the questions in the activity.

Materials Needed

- The AirBeam2 particulate matter sensor and paired Android phone (a paired AirBeam2 and phone will have matching labels)
- Wi-Fi internet access
- Pen/pencil/crayons
- Tape measurer (optional)
- Data Collection Worksheet or paper for taking notes and recording your answers
- Printed or digital map to create a walking route to a vegetative barrier
  - Identify a nearby area with an existing vegetative barrier or a location where one may be helpful and plan a walking route. Google Maps or Apple Maps may be helpful for mapping your route, or you can print out a map.

TIP

This activity can be done with other air sensors, too!

Time Requirement

The main activity can be tailored to any given time period by adjusting the length of time spent outside with the AirBeam2. Under the instructor's guidance, at least 60 minutes is recommended, while at least 75 minutes is advised for people guiding themselves through the activity. The extension activity will take additional time–at least 45 minutes is recommended.

Age Range

The material in this lesson is geared towards middle school aged students (about a 6^{th} grade level) through adults. The materials can be adapted for younger audiences.

Technology Disclaimer

While we discuss using specific air sensors for the activities, other air sensors that measure particulate matter may be used instead.[1]

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[1] Note: EPA makes no endorsement of AirBeam2 or any other air sensor technology.

Introduction

In this activity, you will use an AirBeam2 PM sensor to measure PM outdoors. Before you get started, you will learn about sources of outdoor PM and why those sources may be of concern. You will then learn about vegetative barriers, how they work, and what types of vegetation make a good barrier. Next, using what you learned about PM sources, you will plan a walking route to a vegetative barrier in your community. Then you will go outside to collect measurements with the AirBeam2. Finally, using the data you collect, you will learn how to interpret your measurements and suggest a location in your community where a new vegetative barrier might be effective.

What Is Particulate Matter?

Particulate matter (PM) is a mixture of very small solid particles and liquid droplets that are suspended in the air. They can be made of soil, soot, dust, pollen, metals, and much more. Scientists often group PM into different classes based on their size. Two common classes of PM are:

PM_{10} – this includes particles that are smaller than 10 micrometers in diameter.

$PM_{2.5}$ – also called fine PM, this includes particles that are smaller than 2.5 micrometers in diameter.

You may not often think in terms of micrometers, so it might be hard to imagine how small these particles are. To give you a better idea, see **Figure 1**. A human hair is approximately 50-70 micrometers (µm) in diameter. You can see that PM_{10} particles could fit many times into the diameter of a human hair. You can fit even more $PM_{2.5}$ particles into the diameter of a human hair, as they are much smaller than PM_{10}!

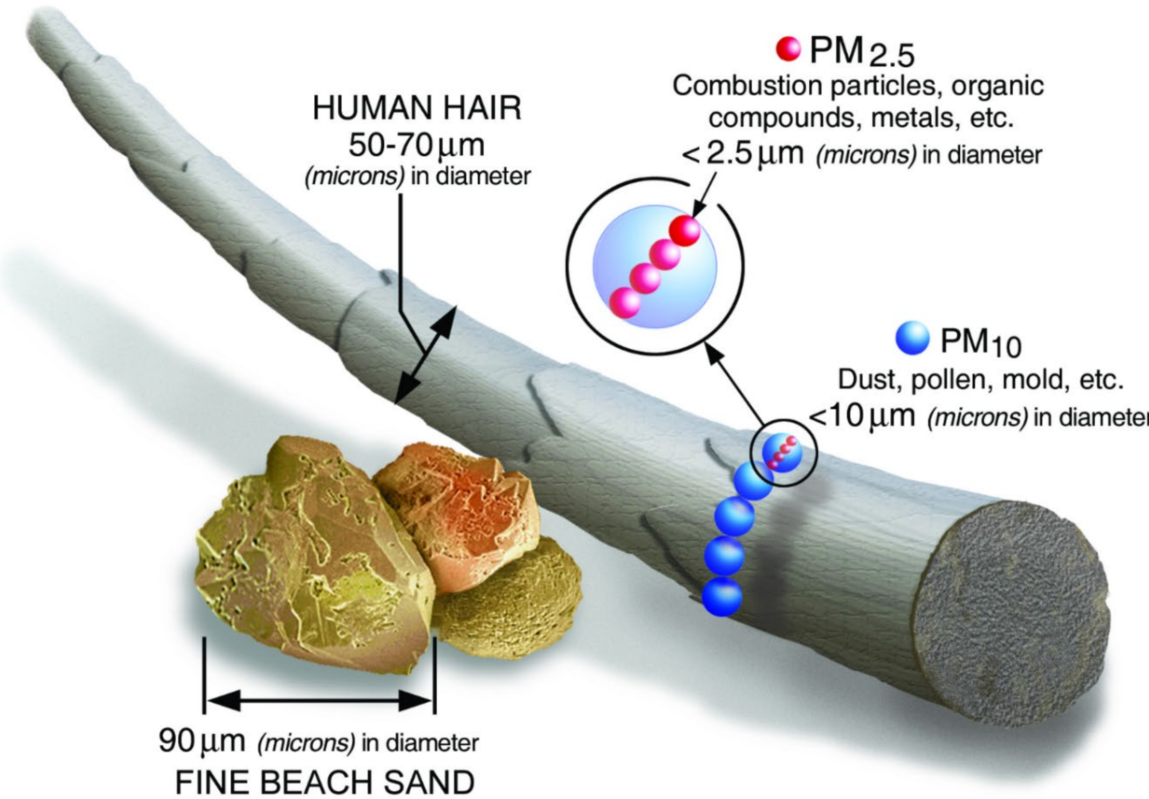


Figure 1. A schematic showing the size of a $PM_{2.5}$ particle and a PM_{10} particle in comparison to a grain of sand and a human hair. Image credit: U.S. EPA.

Where Does Particulate Matter Come from?

There are many sources of PM in your environment, produced by both human-made and natural sources. Below are some examples of sources you may find in your community.

Roadways and Vehicles:

PM is generated several ways from roadways and vehicles. $PM_{2.5}$ is generally produced from combustion processes and is consequently found in tailpipe exhaust from burning gasoline or diesel fuel in passenger vehicles or large trucks. PM_{10} is generally produced from mechanical processes that generate dust, such as when a vehicle drives over a dirt road or the wind kicks up dust over open fields. Roadways and vehicles also produce PM include when tires wear down over time and from brake pad debris when vehicles brake. These common sources are summarized in **Figure 2** below:

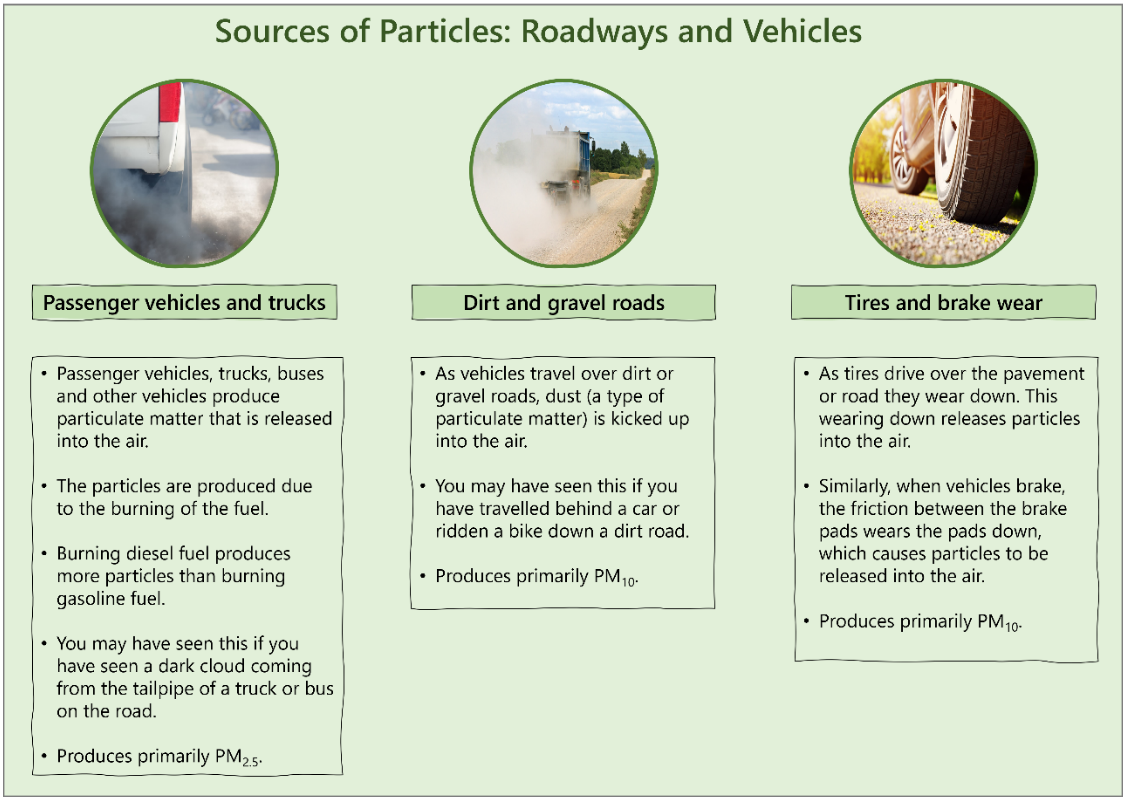


Figure 2. Common sources of PM from roadways and vehicles include diesel vehicles and trucks, dirt and gravel roads, and tire and brakes wearing down over time.

Nonroad and Other Sources:

Nonroad sources include vehicles, engines, and equipment used for construction, agriculture, recreation, and other purposes. These include ferries, freighters, railroads, and machinery used at construction sites, in mines or in agriculture. PM can be generated from other sources too. For instance, PM_{10} might be generated from quarries, which create dust. Power plants burn fuel to generate power and can create PM from the combustion process; however, loading in fuel or removing fuel waste can also create PM. Wood burning appliances, such as stoves, boilers, or heaters produce $PM_{2.5}$. Wildfires and burning of leaves, trash, or other material either in open burns or in fire pits, chimeneas, or backyard burn barrels also contribute to PM in the atmosphere. These sources are summarized in **Figure 3**.

Sources of Particles: Nonroad and Other

Nonroad Sources

Sources of $PM_{2.5}$ from equipment and machinery that do not travel on roadways includes:

- Ferries
- Freighters
- Construction site equipment
- Mining equipment
- Agricultural equipment

Wood Burning Appliances

- You may have seen smoke coming from a wood boiler wood stove, wood heater, or other appliances that use wood for fuel.
- These appliances emit $PM_{2.5}$ particles into the air.

Power Plants

- Power plants can also contribute PM to the atmosphere.
- Power plants burn fuel to generate power. Depending on the fuel used, the power plant might produce mainly PM_{10} or $PM_{2.5}$ particles.

Quarries

- Quarries can contribute PM to the atmosphere.
- Quarries are responsible for digging up sand and gravel from the ground. This can produce dust, which is mostly PM_{10} particles.

Wildfires and Burning

- Wildfires and burning of leaves and trash produce large quantities of mainly $PM_{2.5}$ particles.
- Other sources of burning that contribute to air pollution include:
    - Fire pits
    - Chimeneas
    - Backyard burn barrels

Figure 3. Examples of common nonroad and other source of PM you might find in your community.

Particulate Matter Movement in the Atmosphere

Depending on its size, PM can stay suspended in the air for as little as a few minutes to as long as many weeks. $PM_{2.5}$ (remember, these particles have a diameter less than 2.5 micrometers) stay in the atmosphere longer. Larger particles, like PM_{10}, fall to the ground faster.

PM can be carried by the wind over long distances before it settles on the ground. Wind is just one way particles are moved in the atmosphere; another is rain. When it rains, PM can be washed out of the air and deposited on the ground.

The time of day can also affect how much PM is in the air. For example, if there is a time of day when more cars are driving, such as during rush hour, or when more trucks or ferries are active, this can lead to higher levels of PM in the air. The time of year, season, and temperature outside may also impact PM levels. For example, when it is cold outside, typically in the winter and spring, people may rely on wood burning heaters to help heat their houses. Another example is that more people may have backyard BBQs or bonfires in the summer months. These burning activities also produce $PM_{2.5}$.

Sometimes, in locations with more truck and vehicle traffic, tall rows of hedges or trees are planted along the side of the roads. This vegetation may help block or reduce PM produced by the vehicles so that the PM levels are lower on the other side of the vegetation, protecting schools, homes, parks, or other places. This helps to reduce the amount of PM people breathe in (which is known as exposure to PM). Many more factors can influence PM movement, but these are some of the more common ones.

How Does Particulate Matter Affect Us?

You might be wondering why you should care about PM. PM can affect your health and your environment in serious ways.

If you are exposed to PM and breathe it in, the particles may deposit in your lungs, causing your lungs to become inflamed and irritated. The size of the particles ($PM_{2.5}$ or PM_{10}) makes a difference!

$PM_{2.5}$ can travel deep into your lungs, causing:

- **Breathing problems**, such as coughing, throat irritation, difficulty breathing, asthma, bronchitis, and many other ailments. Some of these problems are short-term; others may become chronic with prolonged exposure.
- **Heart problems**, such as heart attacks or an irregular heartbeat.

PM_{10} does not travel as deep into the lungs as the particles are larger and body is better at filtering them out. Generally, PM_{10} affects the upper respiratory tract. These particles are most commonly associated with eye, nose, and throat irritation.

In the environment, PM can cause many issues too. For example, PM can cause the air to become hazy, which reduces visibility or your ability to see far away. Have you looked outside of your house on a clear day and then again on a day when the air is polluted, perhaps by smoke from a forest fire? You might not be able to see as far when there is smoke in the air; this is because of PM. **Figure 4** shows some health and environmental effects of PM.

The Airbeam2 sensor you will use measures PM_{10}, $PM_{2.5}$, and PM_1 (particles smaller than 1 micrometer in diameter). Because of its important health effects, you will focus on monitoring $PM_{2.5}$ in this activity.

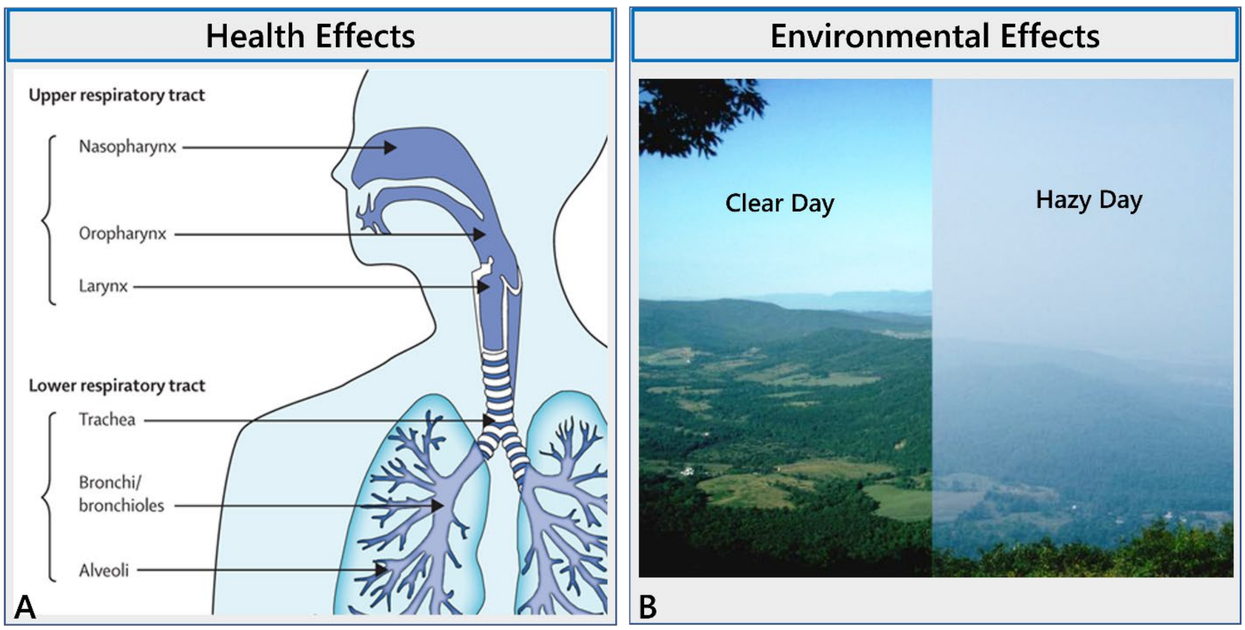


Figure 4. Panel A shows the areas of the respiratory system that can be affected by breathing in PM (*The Lancet* 2014 3831581-1592DOI: (10.1016/S0140-6736(14)60617-6), used with permission). Panel B shows how difficult it is to see when the air is polluted (hazy day) versus when the air is clean (clear day).

Vegetation in Our Environment

As mentioned above, vegetation can help reduce the amount of pollution people breathe in while at school, home, work, and other places next to the busy roads and highways. We will discuss this more in a moment, but first let's consider the benefits of vegetation overall.

Vegetation is an overall term used to describe plants and trees. You might be able to look outside the window right now and see a variety of vegetation, from small plants and shrubs to large trees and hedges. Vegetation serves many roles in our everyday lives. A few of the many benefits of vegetation are shown in **Figure 5**.

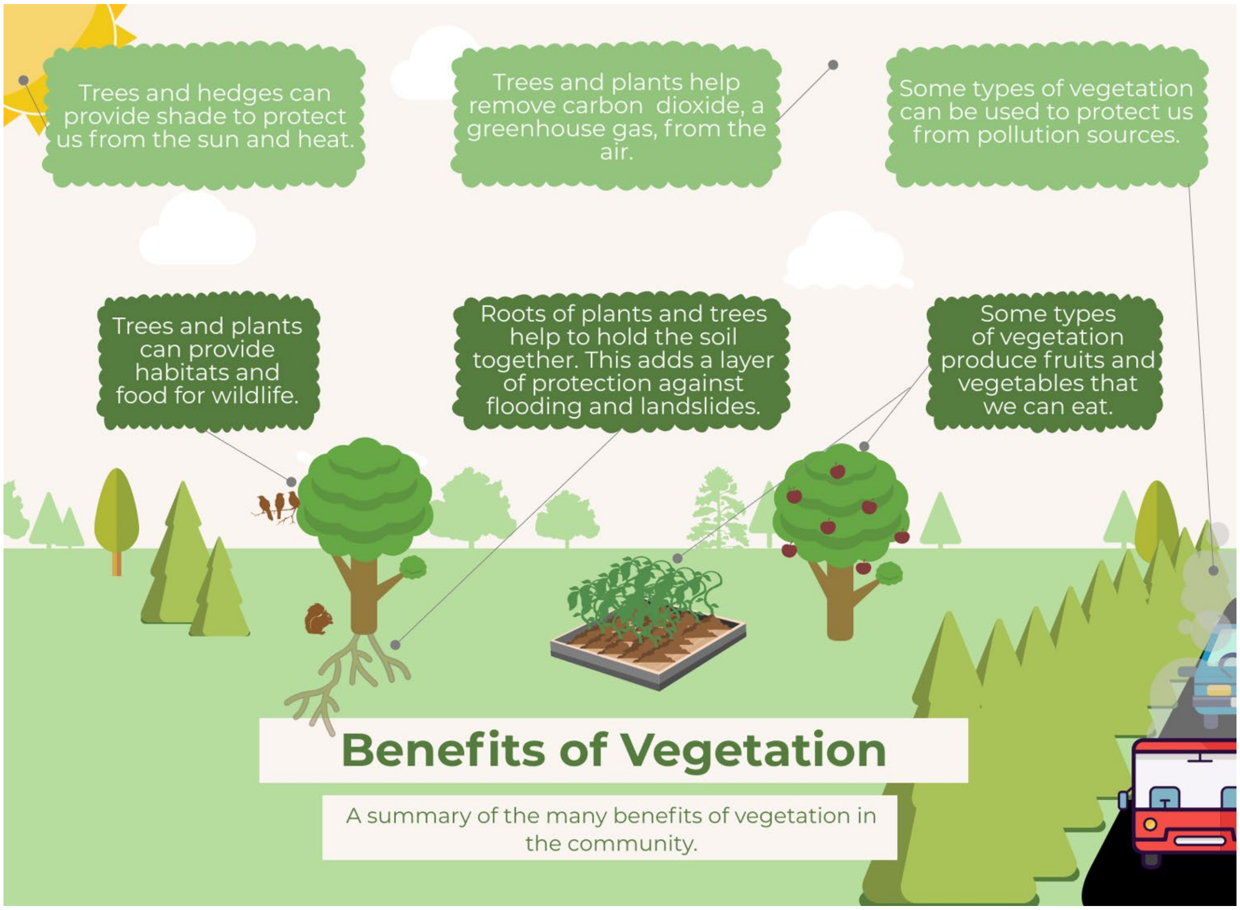


Figure 5. A summary of a few of the many benefits of vegetation in the community.

Pre-Activity Discussion Question

Can you think of any other benefits of vegetation? Fill in your answers in bubble ① on your **Data Collection Worksheet.**

What are Vegetative Barriers?

Let's focus on one specific benefit of trees and plants: their ability to act as barriers or filters of air pollution. From Figure 5, we see that some types of vegetation can be used to protect us from pollution sources. But what is a vegetative barrier? A vegetative barrier is a row of trees, hedges, plants, or other vegetation that is planted near a pollution source to reduce pollution, and thereby exposures. A vegetative barrier is placed between the pollution source and the area where people need to be protected. Typically, vegetative barriers are used along busy roads to prevent roadway pollution from reaching places where people spend time, such as nearby houses, schools, sidewalks, or parks along the road. Two examples of roadway vegetative barriers are shown below in **Figure 6**.

Figure 6. Two examples of vegetative barriers next to roads in the United States: Photo source: Baldauf et al. 2017 (doi: 10.1016/j.trd.2017.03.013)

This may leave you asking: how do vegetative barriers work? What types of vegetation are best for barriers? What characteristics make a good vegetative barrier? We will help answer these questions in the following sections.

How Do Vegetative Barriers Work?

As you learned above, motor vehicles are a source of PM in the atmosphere. Because of this, busy roadways with many large truck and passenger vehicles will have higher levels of PM. Remember that once PM is in the air, it doesn't just sit still; it travels around. This means that people may be exposed to higher levels of PM as they spend time on sidewalks or in shops, houses, schools, parks, or other places next to busy roadways, which could be bad for their health. Research by the U.S. EPA and others has shown that planting trees and/or plants next to busy roadways can help to reduce pollution. For more information about this research, see the EPA vegetative barrier curriculum using the link at the end of this section.

Trees and plants next to busy roadways can help to reduce pollution in two ways:

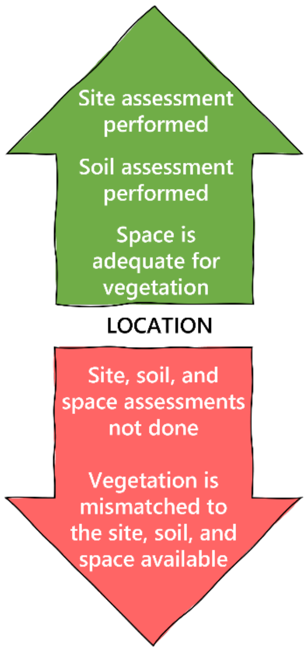
1. They act as a physical barrier and block particles from getting through, similar to how a fence prevents most things from passing through
2. They can act as a filter for particles that make it through the physical barrier, as particles may stick to or settle onto leaf surfaces rather than travelling around the leaves and through the foliage.

You may be wondering if other types of barriers would also work to block PM. The answer is yes – walls, fences, and vegetation can all be used to minimize pollution. Unlike a fence or wall, vegetation provides more surface area for PM to deposit onto, has environmental benefits (e.g., soil stabilization and converting carbon dioxide into oxygen for us to breathe), and is generally more enjoyable to look at! Over time, vegetation can grow and change, which can lead to further benefits but also some concerns. These considerations are discussed in the next section.

For more information about vegetative barriers research, see: EPA vegetative barrier curriculum background (https://cfpub.epa.gov/si/si_public_record_report.cfm?dirEntryId=349632&Lab=CEMM).

What Conditions and Vegetation Make for a Better Vegetative Barrier?

Not all trees or plants make effective vegetative barriers, and not all locations or conditions are appropriate to grow a vegetative barrier. Certain characteristics make plants or trees better at blocking and filtering PM, and certain factors should be considered when choosing a location. Some of these considerations are outlined below:



<u>Location/Siting Considerations</u>

If planning a new vegetative barrier or installing any vegetation, make sure to start by understanding the location. Understanding the location in advance of the installation or improvement of a vegetative barrier is important for the future success of the vegetation.

When planting trees, start with a **site assessment** to help you understand any limitations that might impact the survival of the vegetation. A site assessment includes:

- Checking for overhead power or telephone lines
- Checking for below-ground structures like power, gas, or electrical or drainage lines
- Checking for local/state restrictions regarding safety (e.g., call before you dig requirements)
- If the location is next to a school or easily accessible by young students or animals, make sure the vegetation is not poisonous

The next step is to do a **soil assessment**. Talk with an arborist or botanical expert at a museum, garden, or nursey for assistance or guidance.

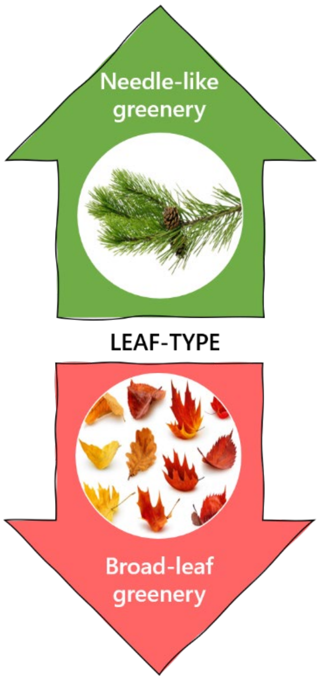
Some questions include:

- Could such an area support woody vegetation?
- Is the soil compacted (hard to dig)? If so, vegetation roots may not thrive.
- Does it drain well but maintain some moisture?
- Are the right nutrients available?
- Is the pH appropriate for the vegetation?

The Morton Arboretum developed the Vegetation Barrier Toolkit for Schools and Communities and Guide #5: Get to Know Your Soil (pages 17-23) within that resource provides instructions for 5 soil tests designed to check for several common soil problems. Those tests have also been adapted for students and included in the Arboretum's Vegetation Barrier Lesson Plan within the Investigating Soil on Your Schoolyard activity (pages 32-37). For more information on what to consider when siting vegetation, check out the **Resources Guide** for additional links and guides.

Finally, a **space assessment** is important to consider the type of vegetation that is appropriate for the space available. An arborist or botanical expert may be able to provide some suggestions or guidance. Some questions include:

- What is the ideal height and area to be covered?
- Is the available space sufficient for the plants to grow and thrive?
- Will this option block sidewalks or people from being able to see clearly?
- How deep will plants roots grow? Shallow roots may impair nearby roadways or sidewalks and may not be good options.



<u>Do the Trees/Plants Lose Their Leaves in Winter?</u>

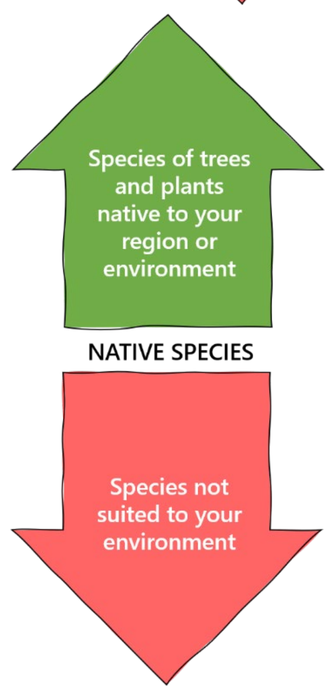
Many evergreen species (those that <u>do not</u> lose their leaves in the winter) are better than deciduous species (those that lose their leaves in the winter) for vegetative barriers. If a plant or tree loses its leaves in the winter, it will become bare, meaning it will not block or filter PM as well in the wintertime.

<u>Leaf Type</u>

Trees with needle-like greenery (e.g., conifers or pine trees) tend to be more effective at filtering out PM than broad leaved trees or plants. This is because the needles create more surface area for PM to deposit onto.

<u>Native Species</u>

Plants and trees that are suited to your environment will thrive better than plants not naturally found there. Native plants can better survive on the amount of rainfall typical in your area. They will be better suited to the local soil and will likely survive the summer and winter temperatures in your region. You can find out more about the types of plants best suited to your environment by speaking with an arborist or botanical expert in your area.



Effective Coverage

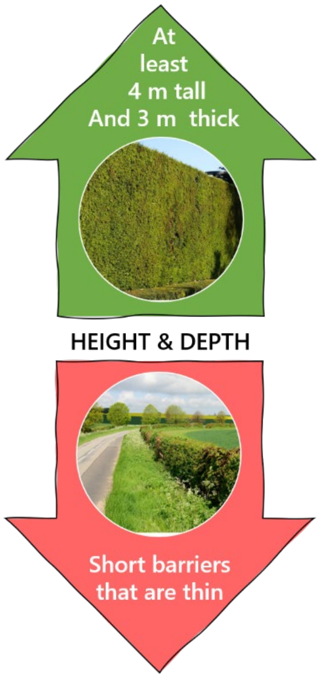
FULL COVERAGE

A vegetative barrier will be most effective if the leaves reach all the way to the ground. If a tree does not have greenery all the way to the ground, another option is to grow shrubs or short bushes next to the tree to fill the gap. An alternate solution is to place a fence in front of or behind the trees to cover the area where the trees do not have leaves.

Making sure the trees or bushes provide a thick cover, essentially creating a wall of greenery, is important for creating an effective vegetative barrier. If there are gaps, missing trees, or the trees are not close to one another, pollutants will be able to pass through. This would mean the vegetative barrier is less effective at blocking PM.

CREATING A WALL

It is important to keep in mind that plants and trees take time to grow. If a new vegetative barrier is planted and the trees or plants are young, it will take time for them to grow to maturity (growing to their full thickness and leafiness). If more mature plants or trees are planted, they may take less time to grow, but will still need to adjust to their new environment. Type of species, water availability, and how young the plants or trees are when they are planted all impact the time it will take for the vegetation to grow and provide maximum protection from PM. Placing a solid fence along the road in addition to vegetation may also create a barrier that will improve even more when the vegetation grows above the top.

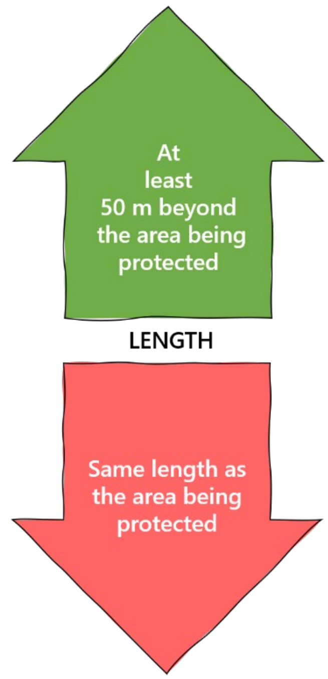


Vegetative Barrier Size and Dimensions

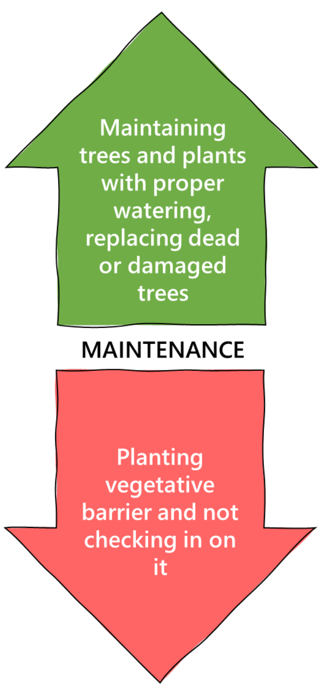
The taller a barrier is the more effective it will be at blocking PM pollution. Typically, the minimum height should be **4 meters**, as this will ensure it is taller than cars or trucks passing by. However, a vegetative barrier of 10 meters or more would be better at reducing pollution levels, assuming the plants' leaves remain consistent all the way to the top.

The thickness of the vegetative barrier is also important. The thicker the barrier, the more leaves there are to help filter out PM. In general, vegetative barriers should be at least **3 meters** thick and, as noted above, gaps should be avoided.

The length of the barrier along the road should extend at least **50 meters** beyond the area being protected (e.g., park, school). This will prevent PM from giong around the edge of the end of the vegetative barrier.



Maintenance



Properly look after the vegetative barrier to ensure it stays effective. This means making sure the trees or plants have enough water, stay free from disease, and that any dead or damaged trees are removed and replaced with healthy ones. Don't forget to consider the possibility that trees may need to be trimmed to remove damaged limbs, maintain good sight lines for vehicles, sidewalk space for pedestrians, and/or maintain clearance for overhead powerlines. Maintenance is an important part of making sure a vegetative barrier stays as effective as possible.

Another important consideration is how planting vegetation might impact other essential activities. For example, if vegetation will be placed near a roadway that requires snow removal or de-icing, how will these materials affect the vegetation?

For more information about growing roadside vegetation barriers, see the Recommendations for Constructing Roadside Vegetation Barriers to Improve Near-Road Air Quality (https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=NRMRL&dirEntryId=321772).

Pre-Activity Discussion Questions

Now you have learned about vegetative barriers and the characteristics that make them effective! In the section below, choose which vegetative barrier you think would be more effective and describe why. Fill in your answers in sections 2 through 4 on your **Data Collection Worksheet**.

OPTION A

OPTION B

Question 2

The best option is______

This is because: ______________________________

____

____

____

OPTION A

OPTION B

Question 3

The best option is______

This is because: ______________________________

____

____

____

OPTION A

OPTION B

Question 4

The best option is______

This is because: ______________________________

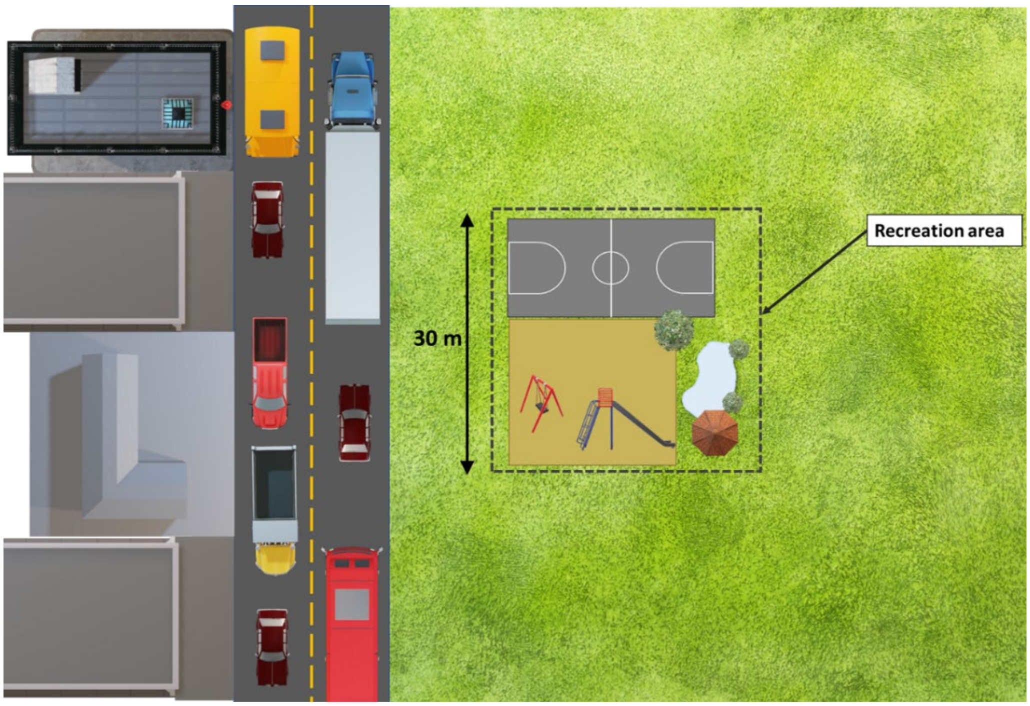
____

____

____

Question 5 (Advanced)

You have been put in charge of planting a vegetative barrier in your community to help protect a recreation area from pollution coming from the nearby busy road.



The map above shows the stretch of busy road and the location of the recreation area. The recreation area is 30 meters long.

To best protect the people who spend time there, what characteristics would you want for the vegetative barrier you would build between the recreation area and the busy road? Fill in your answers in bubble ⑤ on your **Data Collection Worksheet**.

a. Length of barrier: ______________________________

b. Depth/thickness of barrier: ____________________

c. Height of barrier: ______________________________

d. Calculate the area of the barrier you would need (*tip*: *area = length x depth):*

e. Calculate the volume of the barrier you would need (*tip*: *volume = length x depth x height):*

f. If you are asked to plant trees that will reach 5 meters in diameter when they are fully gown, how many trees would you need to cover the whole **length** of your barrier *(tip: you can approximate the tree as a square where the sides are 5 meters long)?*

Procedure

Part 1: Predictions and Sampling

1. Investigate your community! Now that you have learned about vegetative barriers, you will try to locate one in your community. To do this, you can use online mapping tools like Google maps (maps.google.com) or mobile phone navigation tools (Google Maps or Apple Maps apps). Viewing the area in satellite view or consulting EnviroAtlas (instructions on how to use this are below) may help you identify locations where vegetative barriers exist. Using your knowledge of where you live and a mapping tool, identify a vegetative barrier in your community. If it is safe to do so, plan a walking path to the barrier. Alternatively, you can just start walking and see what you find. To help in your search, consider vegetative barriers that might be:

    - Near sidewalks next to busy roadways
    - Near the ferry port
    - Near school buildings
    - Near playgrounds
    - Near sports fields
    - Near bus/car pick-up/drop-off areas

2. Another useful tool to use for researching your community is EnviroAtlas (**Figure 7**).

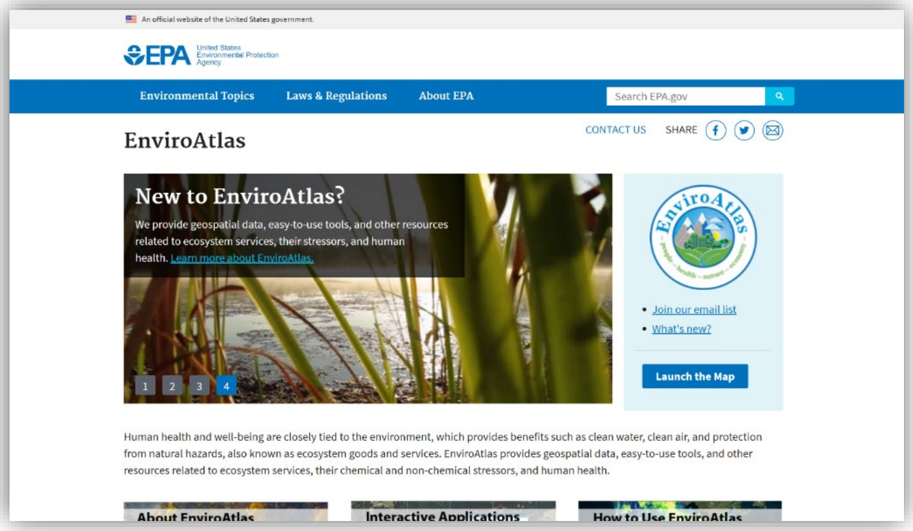


Figure 7. The U.S. EPA EnviroAtlas homepage. (Image credit: https://enviroatlas.epa.gov/enviroatlas)

EnviroAtlas was developed by the U.S. EPA and provides geospatial data, easy-to-use tools, and other resources related to ecosystem services and human health. Use EnvrioAtlas to help inform you of the types of land use in your immediate area.

- To do this, navigate to https://enviroatlas.epa.gov/enviroatlas/interactivemap/
- Click on "Launch the Map"
- Navigate by zooming in all the way to your community or the area you plan to walk
- On the left-hand side bar, click the "Land Cover: Type" category
- From the list, select "the National Land Cover Database (NLCD 2011 Conterminous US Only)" layer, as shown in **Figure 8.**
- The map will be shaded to indicate the different types of land use in the area.

Another useful option is the "Near-Road Environments" category, shown in **Figure 9**.

- In this tab, you have the option of selecting a variety of different layers that will help show you information about green space and vegetation near roads. For example, the "Population near major roadway with little to no tree buffer" layer will color the map if the residents within 90 meters of a major roadway are protected from the road by a tree buffer.
- Note: certain map layers are available for the whole nation (noted by the "N" symbol), while others are only available for specific communities (noted by the "C" symbol). If you click on a layer and it does not show up, it is possible that the data is currently unavailable for your community/area.

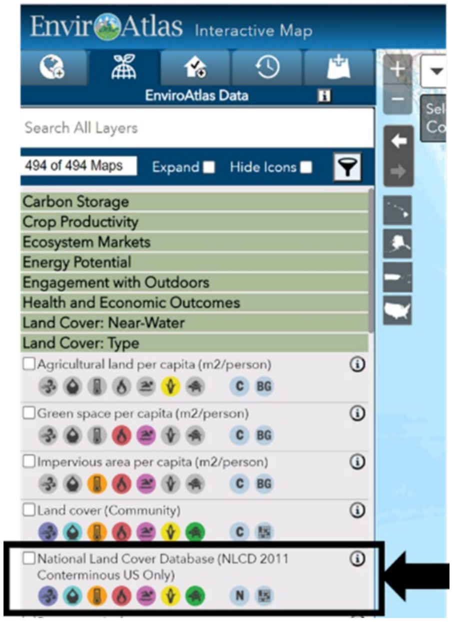


Figure 9. A screenshot showing the suggested (black arrow) layer to select when using the Land Cover type category in EnviroAtlas to inform you of the land use in your community.

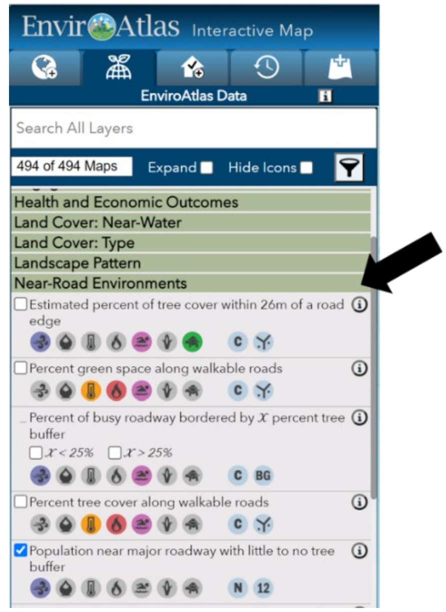
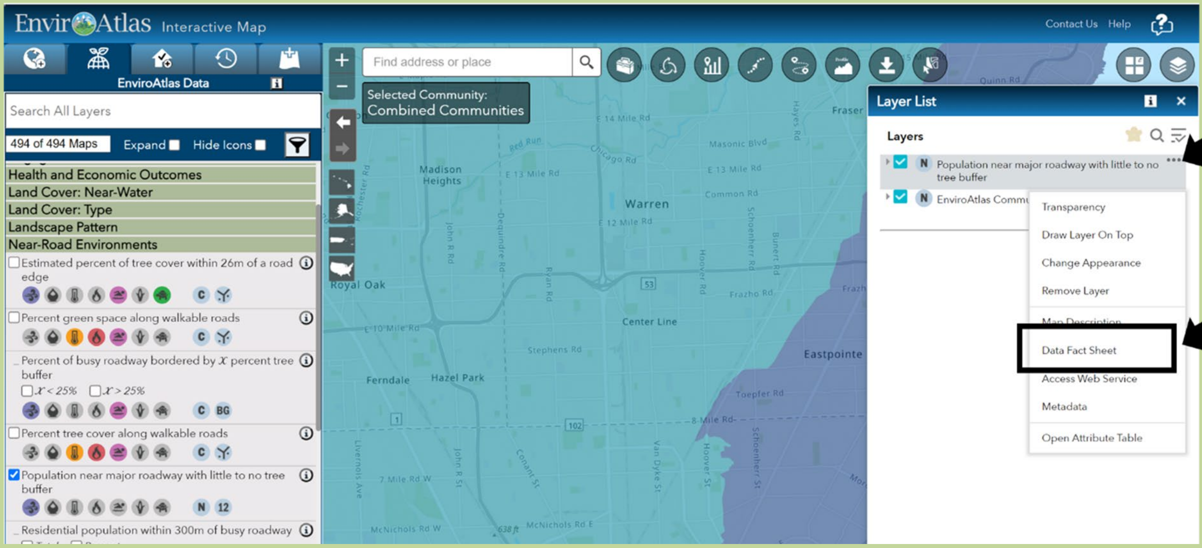


Figure 9. A screenshot showing the Near Road Environments layer.

TIP

In EnviroAtlas, if you would like to know more about a certain layer and the information it provides, you can access the data sheet by:

- Selecting the layer by clicking the checkbox.
- On the right side of the screen, click the three dots icon next to the layer to see a drop-down menu of options.
- Click on the "Data Fact Sheet" option to open a PDF containing information about the data layer.



3. If you have access to a printer, print out your map. An example map is shown in **Figure 10**. If you do not print a map, note the locations on your **Data Collection Worksheet** in bubble ⑥.
    a. On your map, identify and mark existing vegetation, especially if there is some form of a vegetative barrier.
    b. Mark your intended walking route.
    c. Mark the locations where you expect to find the highest and lowest PM levels and circle them on your map.
        i. Focus on areas where there appears to be a vegetative barrier and predict if it increases or decreases the PM levels.
4. Keep in mind the time of day you will be collecting your measurements–when do you expect high levels of PM from roadways? When do you expect high levels of PM around schools or

parks? When do you expect high levels of PM from other sources or non-road mobile sources?

5. Keep in mind what season it is. Will there be more activities outside that generate PM? For instance, during the summer, do ferries operate more due to tourists, or is there more traffic on the roads? In the fall and winter, is there more wood burning indoors or outside?

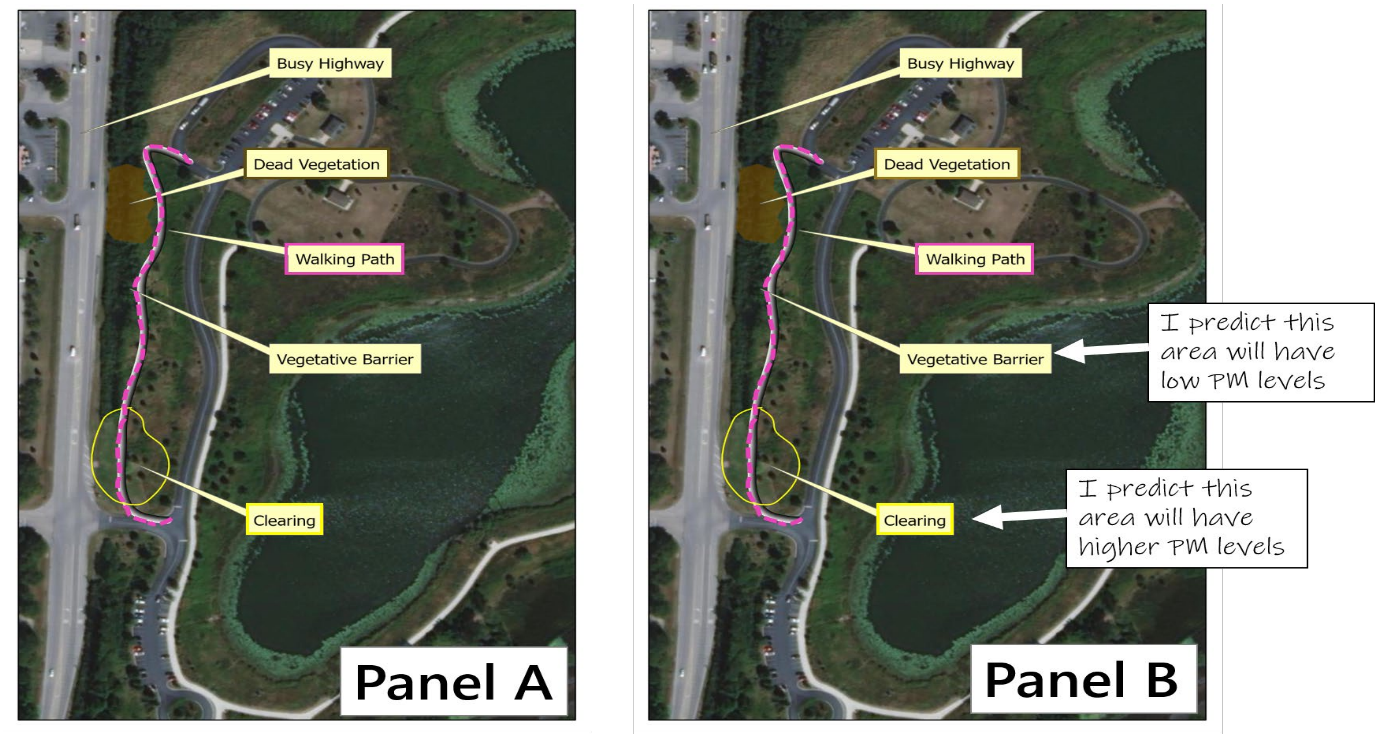


Figure 10. Panel A: An example of a walking map. The walking path in pink follows along a vegetative barrier and to a clearing where no vegetative barrier exists. Panel B: The same map as Panel A but marked to show predictions of where the highest and lowest PM levels might occur.

Part Two: Data Collection with the AirBeam2 Sensor

1. Now, we'll collect $PM_{2.5}$ measurements with the AirBeam2 sensor! Before going on your planned walking route, spend time familiarizing yourself with how the AirBeam2 sensor and AirCasting phone app record data. You may want to do a trial run. Instructions on how use the AirBeam2 and the AirCasting app are in the **Quick Start Guide** document. Remember, you must be connected to Wi-Fi to start a session.

Important Note

Make sure you give your AirCasting session a unique and descriptive title. For example, you can use "Community walk" along with your initials and today's date to name your session. Remember, people will be able to see your information, so be careful on how you identify your session. Tags can also be used to add additional identifying information to your AirCasting session.

2. Remember to select the $PM_{2.5}$ reading on the AirCasting app by clicking on $PM_{2.5}$ from the dashboard.

3. Also recall that the AirBeam2 allows you to view an average of your $PM_{2.5}$ measurements (Avg PM), the current $PM_{2.5}$ measurement (Now PM), and the highest $PM_{2.5}$ measurement (Peak PM). Now PM is the best to view as it tells you what $PM_{2.5}$ level you are currently measuring. See **Figure 11**.

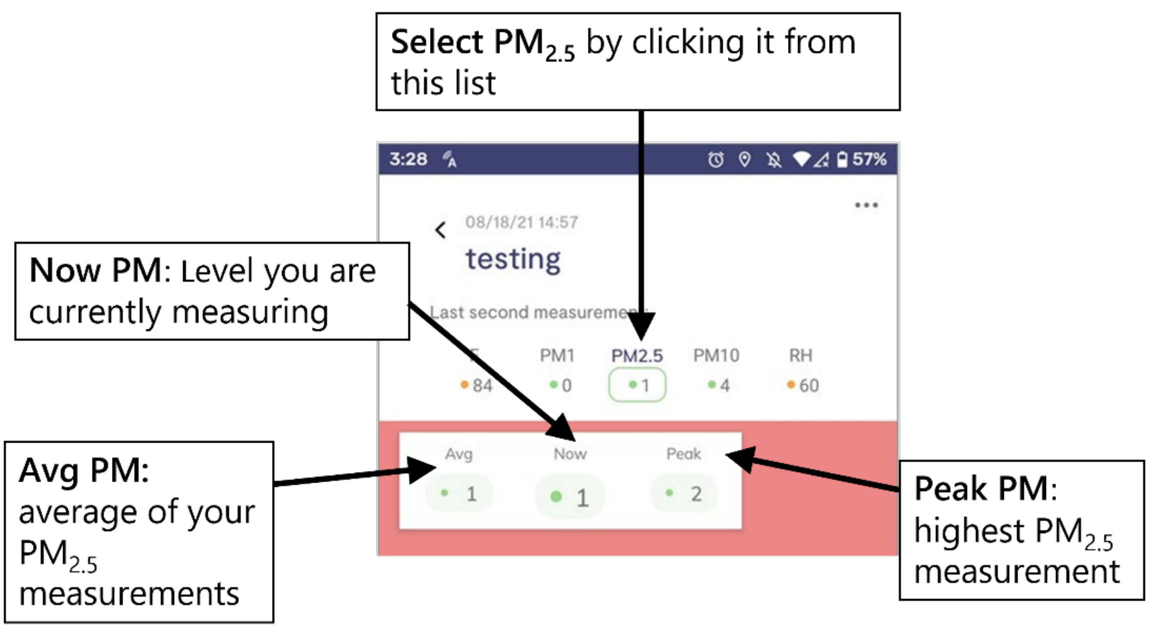


Figure 11. Reminder of the data view on the Aircasting app and what each of the values mean.

4. Go to AirCasting! Use your printed map or the map in the AirCasting app to follow the walking route you have planned. When using the app, Wi-Fi or internet connectivity is not needed during the walk. Don't forget to take the AirBeam2 sensor and phone with you!

5. Once you identify where you are going (either through using a map in real-time or a predetermined route), visit some of the locations where you expect to observe higher $PM_{2.5}$ concentrations. Look to see if those locations have vegetative barriers or a potential place to install a vegetative barrier if it is alongside a roadway.

6. One more thing before you head outside. The wind direction will play an important role in your measurements, especially if you are investigating a vegetative barrier. There is nothing we can do to change the wind direction when we make measurements, but we can note it down to help interpret our results later. **Figure 12** shows some examples of how the wind direction might influence your measurements.
    a. If the wind is blowing the PM from the pollution source away from you, you may not detect PM associated with the source.
        i. In this case, if you stand still and face the pollution source, you will not feel wind on your face. You might feel the wind on the back of your head or your hair blowing from behind you into your face.
    b. If the wind is blowing PM from the source towards you, you will likely be able to measure PM from the source.
        i. In this case, if you stand still and face the pollution source, you will feel wind on your face. Note that if you are facing a vegetative barrier that is between you and the pollution source, the barrier may block the wind. If the barrier was not there, the wind would be blowing on you.
    c. If the wind is blowing in another direction, such as parallel to the source or diagonally, it is possible you are measuring some PM from the source, but not all of it.

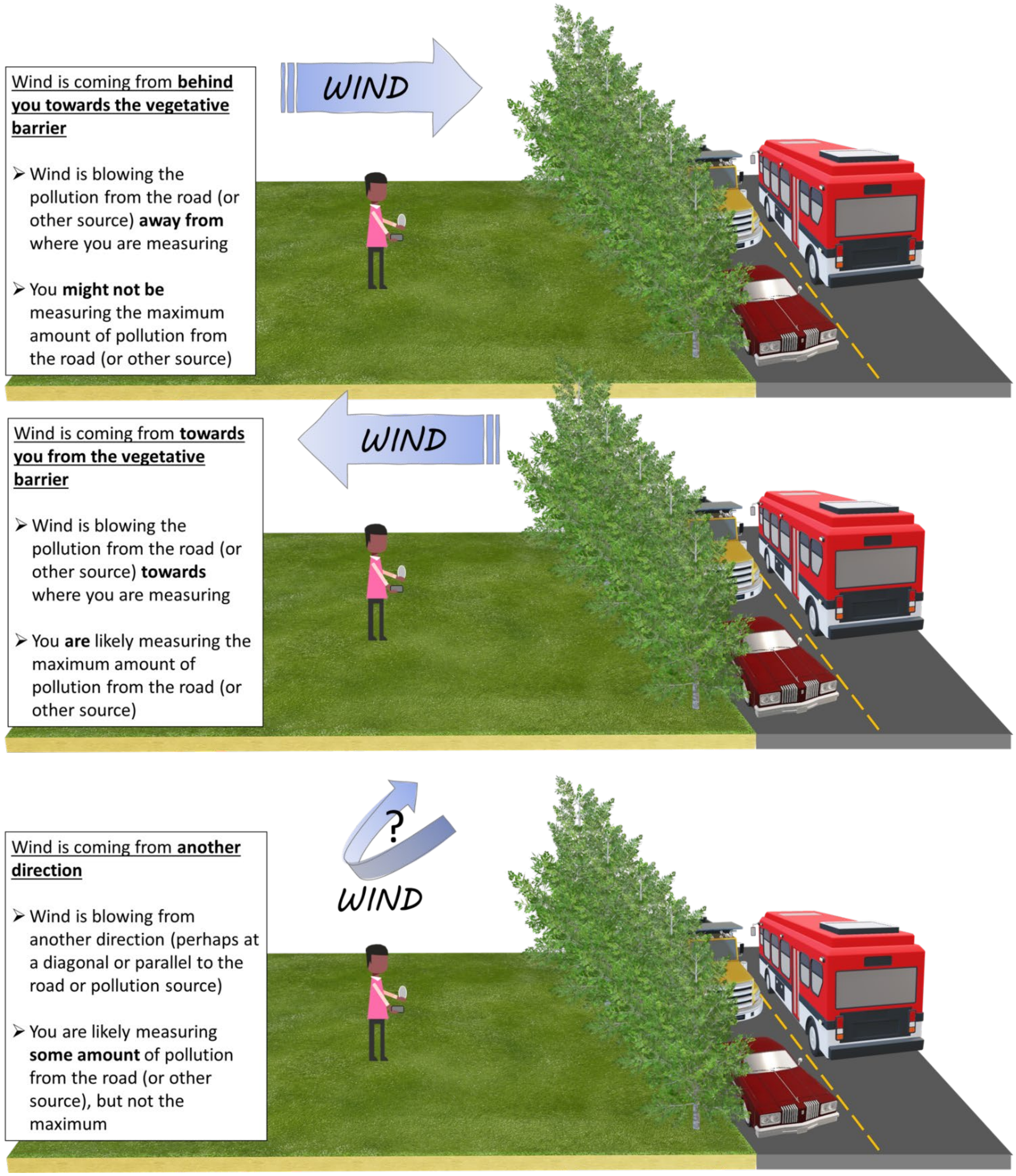


Figure 12. Illustrations showing how the wind direction might influence your PM measurements

Important Note

- Ensure you have a GPS signal for your AirCasting session and load the map in the AirCasting app before heading outside. This will allow you to map your session and upload your data to the map on http://aircasting.habitatmap.org/mobile_map.
- A Wi-Fi connection is only needed to begin your AirCasting session and to upload your data to the map when you are finished.

Observations

1. Be sure to take notes and photos in the AirCasting app as you notice the "Now PM" $PM_{2.5}$ levels changing. Add written observations to your **Data Collection Worksheet** in box ⑦. These pictures and notes might help you understand your measurements later.
    a. Examples of written observations could be:
        - I/we walked alongside a large group of trees and bushes, with the other side running alongside a roadway
        - I/we walked alongside a roadway without vegetation
        - I/we walked past someone burning wood
        - I/we walked past buses/trucks/cars
        - It started raining at 2:00 pm, and then got windy at 2:15 pm
2. If you are able to find a vegetative barrier in your community during your walk, this is your opportunity to collect measurements! **Only perform the following steps if it is safe to do so.**
    a. **BARRIER DESCRIPTION.** Describe the visual characteristics of the barrier. How tall do you estimate it is? Are there gaps? Is it fully gown? Does it reach all the way to the ground? Fill in your answer in box ⑧ on your **Data Collection Worksheet**.
    b. **WIND AND WEATHER**. What are the weather conditions during your measurements? The wind conditions are especially important. Note the wind direction and strength during your measurements by facing the vegetative barrier. Note if the wind is blowing towards you, away from you, or in some other direction. Fill in your results in section ⑨ of the **Data Collection Worksheet**.
        - If you need help deciding which way the wind is blowing, and if it is safe to do so, try standing in one place and slowly turning until you feel the wind in your face. See **Figure 12** for additional information.
    c. **BARRIER VS. NO BARRIER.** Take measurements on the side of the vegetation barrier away from the road/pollution source but extend your measurements past where the

barrier ends. This will allow you to see the difference in $PM_{2.5}$ values when there is and is not a barrier in place. Write down the conditions during your measurements. For example, if the vegetative barrier is next to a road, is the road busy or quiet? Is there a lot of truck traffic or does the traffic mostly include passenger vehicles? If the barrier is by another PM pollution source, is that source operating? Fill in your results in section ⑩ of the **Data Collection Worksheet.**

d. **DISTANCE FROM BARRIER.** Make measurements at different distances from the barrier, moving away from the road and the vegetative barrier. You could do this by measuring PM right next to the barrier and, if there is safe access, walk 10 feet away from the barrier and measure again for a few minutes. You can estimate the distance or use a measuring tape to be more accurate. If there is still safe access, walk another 10 feet away (for a total of 20 feet from the barrier). If there is limited safe access as you move away from the barrier, try using shorter distances (for example, 5 feet). Fill in your results in section ⑪ of the **Data Collection Worksheet.**

e. **HEIGHT.** If possible, try measuring at different heights up and down the barrier. Fill in your results in section ⑫ of the **Data Collection Worksheet.** Some ideas include:

- Holding the sensor close to the ground (to see if the vegetation adequately extends to the ground and is properly "blocking" PM from the road),
- Holding the sensor about 4 feet from the ground (which would be an example of a young child's breathing height),
- Holding the sensor at 6 feet above the ground (which would be an example of a larger adult's breathing height).

Do you see a difference in the $PM_{2.5}$ levels? Mark down the $PM_{2.5}$ level at each height on your **Data Collection Worksheet** to review more closely later.

f. **GAPS**. Do you notice any gaps or changes in the density of the barrier? Gaps could include open spaces or dead vegetation. If you notice any gaps, measure PM in the gaps to see if your $PM_{2.5}$ values change. Fill in your results in section ⑬ of the **Data Collection Worksheet.**

g. If you have a plant identification app on your phone, consider using it to identify the species of trees or plants that create the barrier. If you don't have access to a plant identification app, try taking a photo on your phone. With the help of your instructor, you can try to identify the tree or plant species with in-house resources or through an internet search.

3. Data are collected on the AirCasting app and are uploaded automatically to http://aircasting.habitatmap.org/mobile_map once you are reconnected to Wi-Fi/Internet. When you get back from your walk, make sure the Android phone has reconnected to Wi-Fi so your AirCasting session can sync with the AirCasting mapping website. If you are using a different air sensor, follow the directions specific to that air sensor, especially if it references crowdsourced or mapping data uploads.

4. On a computer, open the AirCasting mapping website and find your uploaded session. You can use your AirCasting **Profile Name** and your AirCasting session **Tags** to help search for your sessions.
5. If you have a paper map, write any notes you made in the AirCasting app during your walk onto your map. Mark the locations where you measured low and high levels of $PM_{2.5}$.

Interpret Your Data

Important Note

Your map should now contain the walking route you identified before your walk, the location of the vegetative barrier you measured, any notes you took during your walk, and locations where you measured and recorded $PM_{2.5}$ levels.

1. What sources of $PM_{2.5}$ did you find on your walk? Fill in your answer in box on your **Data Collection Worksheet.**
2. What were the $PM_{2.5}$ levels you saw on your walking route? Were the levels what you expected them to be? Why or why not? Fill in your answer in box 15 on your **Data Collection Worksheet.**
3. Where were $PM_{2.5}$ levels highest? Why do you think this was the case? Fill in your answer in box 16 on your **Data Collection Worksheet.**
4. Did you collect data at multiple times of the day? Was one time at the same location higher than the other time(s)? Why do you think this was the case? Fill in your answer in box 17 on your **Data Collection Worksheet.**
5. Where were $PM_{2.5}$ levels lowest? Why do you think this was the case? Fill in your answer in box 18 on your **Data Collection Worksheet.**
6. In each of the areas where you saw higher $PM_{2.5}$ levels, would it make sense to add a vegetative barrier? Why or why not? Keep in mind any obstructions and the space available in the area for plants to grow. Fill in your answer in box 19 on your **Data Collection Worksheet.**
7. Can you identify a location where it would be beneficial to add a vegetative barrier? Why did you choose this location? Fill in your answer in box 20 on your **Data Collection Worksheet.**
8. Describe the characteristics that you think would create an effective vegetative barrier in this area. How would a barrier in this location benefit the community? Were there houses, a park, school, or community center near the road? Fill in your answer in box 21 on your **Data Collection Worksheet.**

Interpret Your Vegetative Barrier Measurements

If you made measurements at a vegetative barrier during your walk, answer the questions below:

1. How did the $PM_{2.5}$ levels change when you measured at different heights up the barrier? Why do you think this is? Fill in your answer in box 22 on your **Data Collection Worksheet.**
2. If you were able to measure at different distances away from the vegetative barrier, how did the $PM_{2.5}$ levels change as you got further away from the barrier? Why do you think that was the case? Fill in your answer in box 23 on your **Data Collection Worksheet.**
3. Did you observe differences in $PM_{2.5}$ levels when you measured with and without a vegetative barrier? Explain your results and possible reasons for your observations. Fill in your answer in box 24 on your **Data Collection Worksheet.**
4. How could the characteristics of the barrier have impacted the PM concentrations you measured? Fill in your answer in bubble 25 on your **Data Collection Worksheet.**
5. Overall, how effective was the vegetative barrier? Look back at the wind and other conditions you noted in box 9 on your **Data Collection Worksheet.** How do you think the wind direction and weather could have played a role in your results? Fill in your answer in box 26 on your **Data Collection Worksheet.**

   Hint: If the wind was blowing the $PM_{2.5}$ away from where you were measuring, this might mean the levels are lower and you may not have been measuring the effect of the barrier.

6. If you could make changes to the vegetative barrier to improve it, what would you change and why? Fill in your answer in box 27 on your **Data Collection Worksheet.**

Extension Activity

Community Garden Planning

Introduction:

You may recall from **Figure 5** that one benefit of some types of vegetation is providing fruits and vegetables for us to eat and sustain life. Sometimes vegetables and fruits are grown in community gardens – a piece of land that community members can share to grow plants.

As you can imagine, the ideal location to plant a community garden will be very different than a location where you would want to plant a vegetative barrier. Since community gardens might grow edible plants that people will use for food, we want to make sure they are located as far *away* from pollution sources as possible to minimize or prevent pollutants from contaminating the soil and depositing onto the fruit and vegetables. Other considerations include the need for sunlight and water and accessibility for the community members.

In this extension activity, you will choose the best place for a community garden. Before starting this activity, use the following resources that provide important information on things to consider when choosing a location for a community garden.

Reading Resources:

- USDA resources about community gardening: https://www.nal.usda.gov/afsic/community-gardening
- Community Garden Guides: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/plantmaterials/technical/publications/?cid=stelprdb1044310
- Historical background on school gardens: https://www.nal.usda.gov/exhibits/ipd/small/exhibits/show/school-gardens/urban-and-rural-school-gardens
- Food safety tips for school gardens: https://fns-prod.azureedge.net/sites/default/files/foodsafety_schoolgardens.pdf

Procedure:

1. Find a map of your school campus, home, or the community area(s) where you intend to plant a garden or use graph paper to draw out the various locations where a community garden is being considered. Include any potential PM sources, landmarks, or structures that may impact the PM levels in the areas that are being considered (e.g., buildings, existing wall, vegetative barrier).

2. Based on the information you learned from the resources above, what you learned about pollution sources in the community from the measurements you took in the main activity, and your knowledge of your community, choose the best location for a community garden and mark it on your map. Realize that if you use the PM sensor to take measurements at these locations, there may be different results or meanings based on what you are measuring and for how long. The Extension Activity is merely a tool help you realize how PM can vary at locations at different times and may make different impacts on the garden.

3. Visit all the possible community garden locations you identified and take PM readings.
    a. TIME OF DAY: Decide what times of the day(s) may be important to take readings. For instance, if the locations are near a roadway, measure during rush hour. If interested in reducing exposures to volunteers, find out if there will be specific times of the day or days of the week in which they meet and try to take measurements at those same times. If possible, take PM readings multiple times of the day, and multiple days of the week at all the possible locations.
        i. It might be helpful to note down the peak PM value as well as the average PM (Avg PM) value to help you in your decision making. For information on where to find these values, see **Figure 12**.
        ii. Keep in mind that if you start you AirCasting session before reaching the possible garden location, your Avg PM value will include measurements from your walk to the location.
    b. COMPARE RESULTS: If you are looking at multiple possible locations, lay out a grid or table of your PM measurements. This will help you to compare readings between locations.

4. How does the location you chose rank in PM readings as compared to the other locations?
    a. Did the different times of the day/days of the week change the PM readings between the locations?
    b. Has this review of all your PM readings changed your recommendations for siting a community garden?
    c. If it has not changed your recommendation, what might you do to reduce PM levels if the selected site has higher readings than the other locations?

Keep in mind, if your chosen location is nearby to a pollution source and no other options are available, you might be able to plant a vegetative barrier in the area. This may help to reduce the PM that reaches the community garden. Growing a vegetative barrier and community garden would take additional thought and planning but might be an appropriate solution that you could investigate further with your local arboretum and community leaders.

The Power of Plants!

How Vegetation Can Help Protect Us from Air Pollution

Goal: Go outside and measure particulate matter (PM) near a vegetative barrier in your community or near your home or school.

In this activity you will learn about:

- Sources of particle pollution
- The benefits of vegetation
- How vegetation can serve as a barrier to block pollution
- The characteristics of an effective vegetative barrier
- How to use the handheld AirBeam2 sensor
- How to interpret the measurements collected by the AirBeam2

O.S. Ryder, S.G. Brown, A.L. Clements, R.M. Duvall, S. Batka, M. Gavin. "The Power of Plants! How Vegetation Can Help Protect Us from Air Pollution", Air Sensor Loan Programs for Remote/Rural Locations and Living Museum, Funded by U.S. EPA, 2022

Safety Precautions:

- Minors should be accompanied by a guardian or parent
- Obey caution signs posted near restricted areas (for example, construction areas, industrial areas, train tracks, or others); do not sample in active construction areas or on train tracks
- Wear bright clothing or a reflective safety vest when conducting air quality measurements near roads
- If walking along roads, please use sidewalks and follow common safety practices near roads
- Pay attention to traffic, roads, and general surroundings!
- Use caution while walking around with the AirBeam2 to avoid tripping or colliding with others
- Use caution in the rain – if it is raining hard, it may be safer to wait until after the rain slows down

Be aware of your surroundings, both for safety and to inform your results

Air Pollution and Particulate Matter (PM)

Pollution is any substance in the air that can cause harm to humans, animals, or the environment

Air pollution includes gas pollutants and particle pollutants

Particulate Matter (PM) is the focus of this activity

Sources of PM are all around us!

What Is PM?

- PM can be made of soil, soot, dust, pollen, metals, and more
- PM is extremely small!
- Classes of PM are based on size:
  - PM_{10} (<10 µm in diameter)
  - $PM_{2.5}$ (<2.5 µm in diameter)

$PM_{2.5}$ is the focus of this activity!

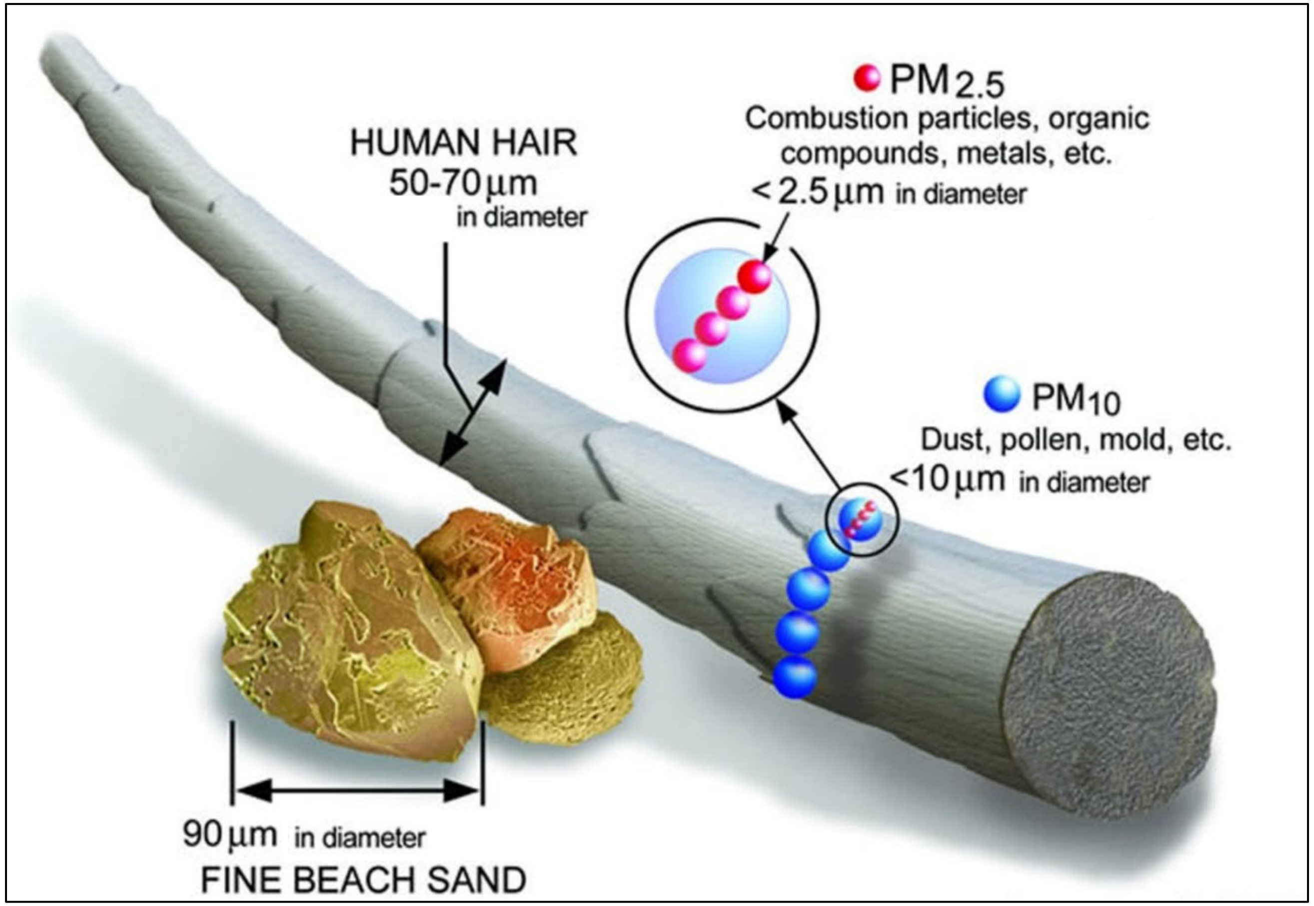


Image Credit: U.S. EPA

Sources of PM in the Environment

Roadways and Vehicles

Passenger vehicles and trucks

$PM_{2.5}$

Dirt and Gravel Roads

PM_{10}

Tires and Brake Wear

$PM_{2.5}$ / PM_{10}

Nonroad and Other Sources

Nonroad Sources

$PM_{2.5}$

Wood Burning Appliances

$PM_{2.5}$

Power Plants

$PM_{2.5}$ / PM_{10}

Quarries

PM_{10}

Wildfires and Burning

$PM_{2.5}$

Factors That Influence PM in the Air

PM can stay in the atmosphere for a few minutes or for weeks, depending on its size

- Smaller particles are lighter, so they can stay in the atmosphere longer
- Larger particles fall to the ground faster

Some factors that influence PM in the air include:

Wind

- PM can be carried over long distances by wind before it settles on the ground.

Rain

- When it rains, PM can be cleared out of the air.

Time of Day

- Time of day can also affect how much or little PM is in the air.
- PM might be higher during rush hour, or when more trucks or ferries are active.

Season or Temperature

- In cold months, people may use wood burning heaters for warmth.
- In summer, people may have BBQs or bonfires.

Trees and Hedges

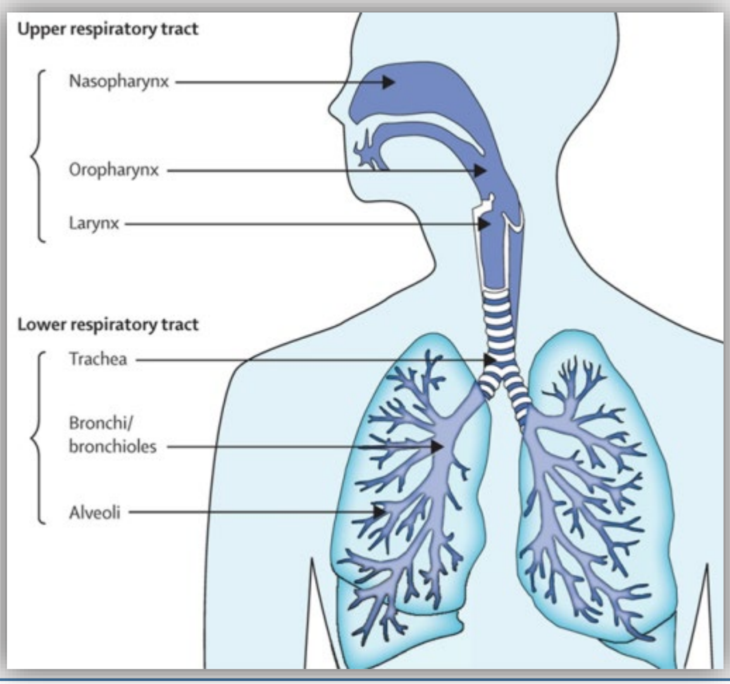
- Trees or hedges planted along busy roads can help block or reduce PM produced by vehicles.

How Does PM Affect Us?

Health Effects

Small particles, like **$PM_{2.5}$**, can travel deep into your lungs, causing:

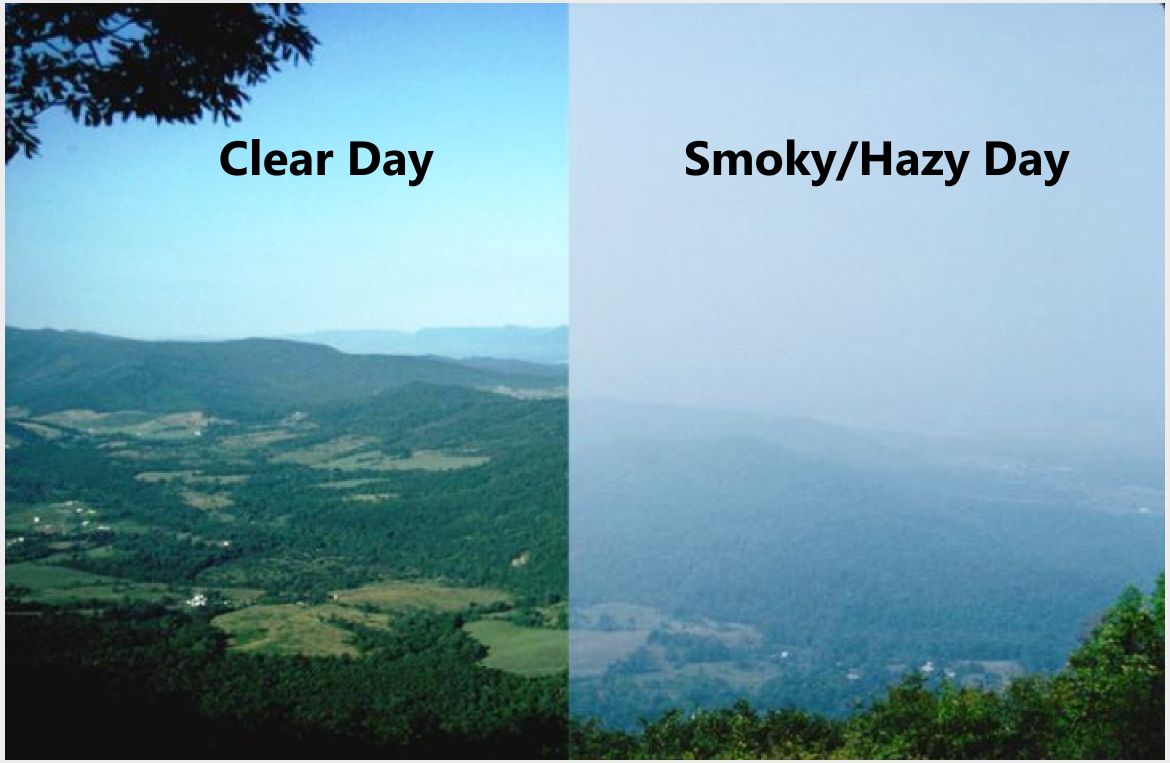
- Breathing problems, such as coughing, throat irritation, difficulty breathing, asthma, bronchitis, and many other ailments.
- Heart problems, such as heart attacks or an irregular heartbeat.



Visibility Effects

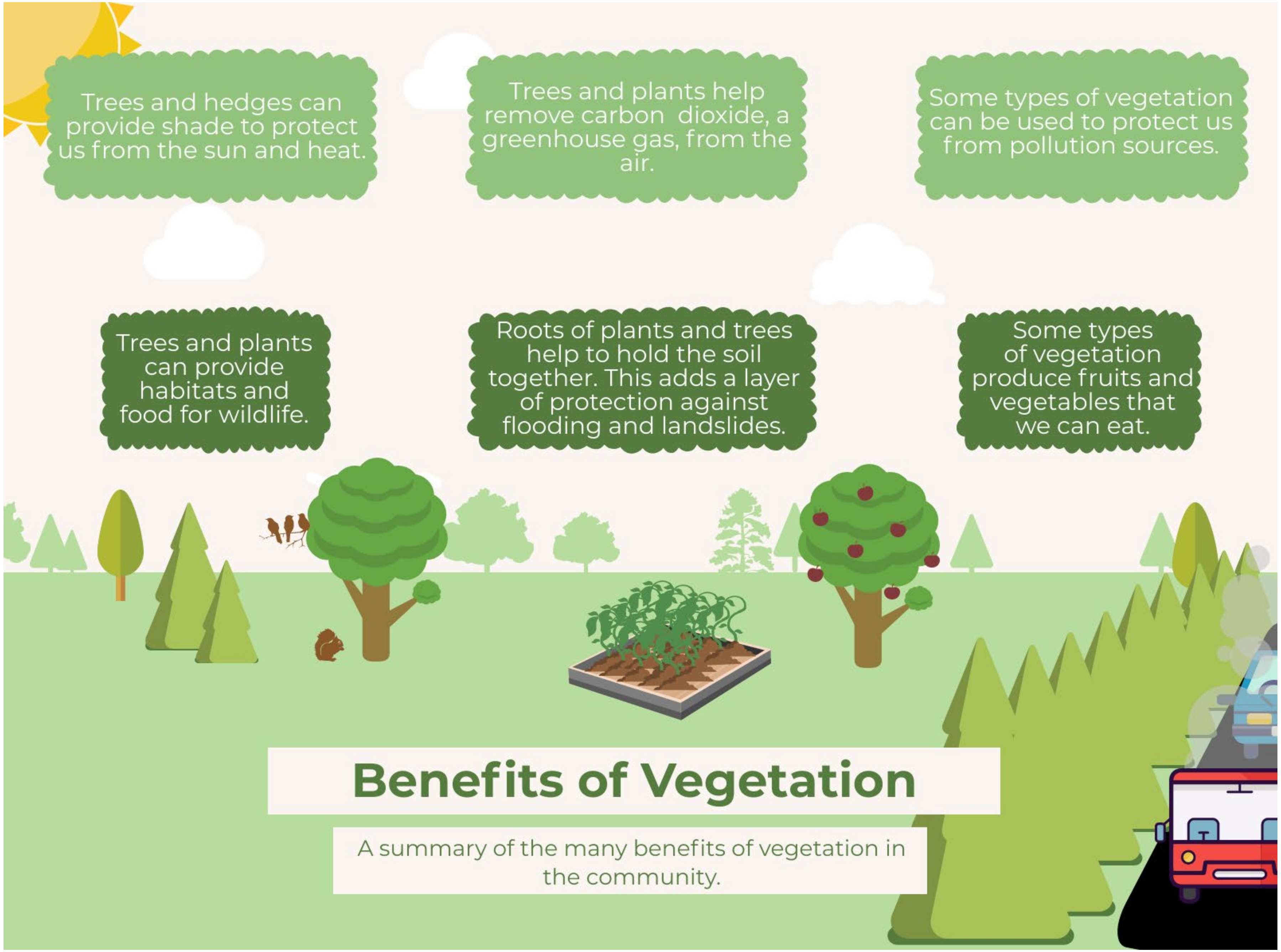
In the environment, PM can cause many issues.

For example, PM can contribute to making the air hazy, which reduces "visibility," or our ability to see far away.



Vegetation in Our Environment

- Vegetation is an overall term used to describe plants and trees
- Vegetation serves many roles in our everyday lives



Let's Discuss

Can you think of any other benefits of vegetation?

Fill in your answers in bubble 1 on your Data Collection Worksheet.

What are Vegetative Barriers?

A vegetative barrier is:

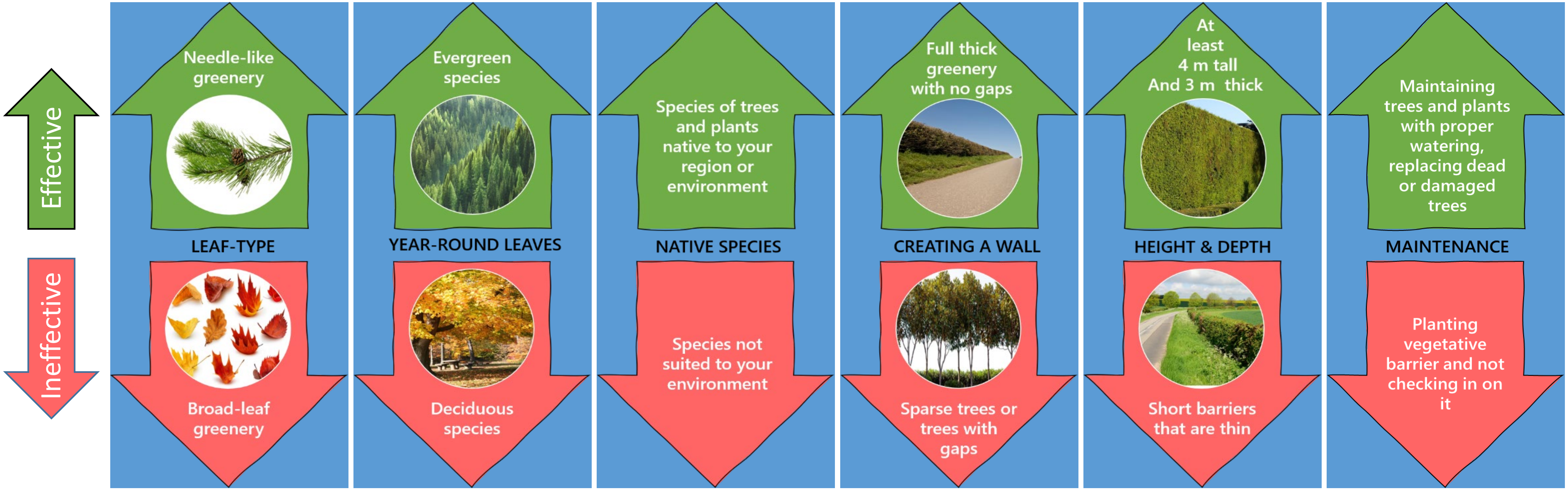
- A row of trees, hedges, plants, or other vegetation planted near a pollution source in order to reduce pollution on the other side.
- Placed <u>between</u> the pollution source and the area where people need to be protected.
- Typically used along busy roads to prevent roadway pollution from reaching places where people spend time, such as nearby houses, nearby schools, sidewalks, or parks along the road.

Two examples of vegetative barriers:

Photo source: Baldauf et al. 2017 (doi: 10.1016/j.trd.2017.03.013)

What Conditions and Vegetation Make for a Better Vegetative Barrier?

A few important characteristics for an effective barrier are:



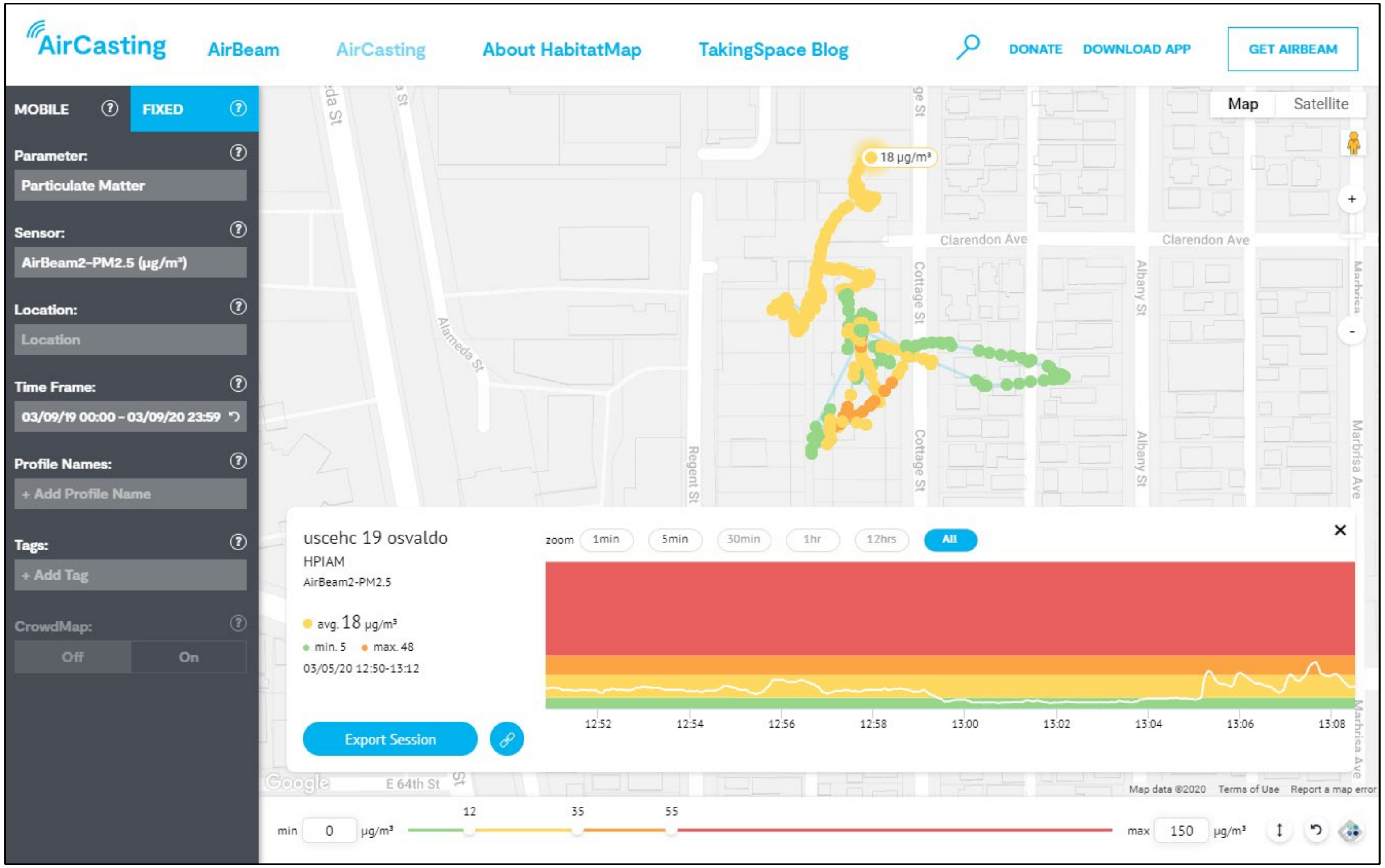
Additional key characteristics are explained in the lesson

You Can Use Handheld PM Sensors Like the AirBeam2 to Measure PM Levels

You 'll carry the AirBeam2 sensor to map the $PM_{2.5}$ where you walk!

The data is recorded and uploaded to the Internet

Later, you can look at the data you collected on a website



Planning Your Route

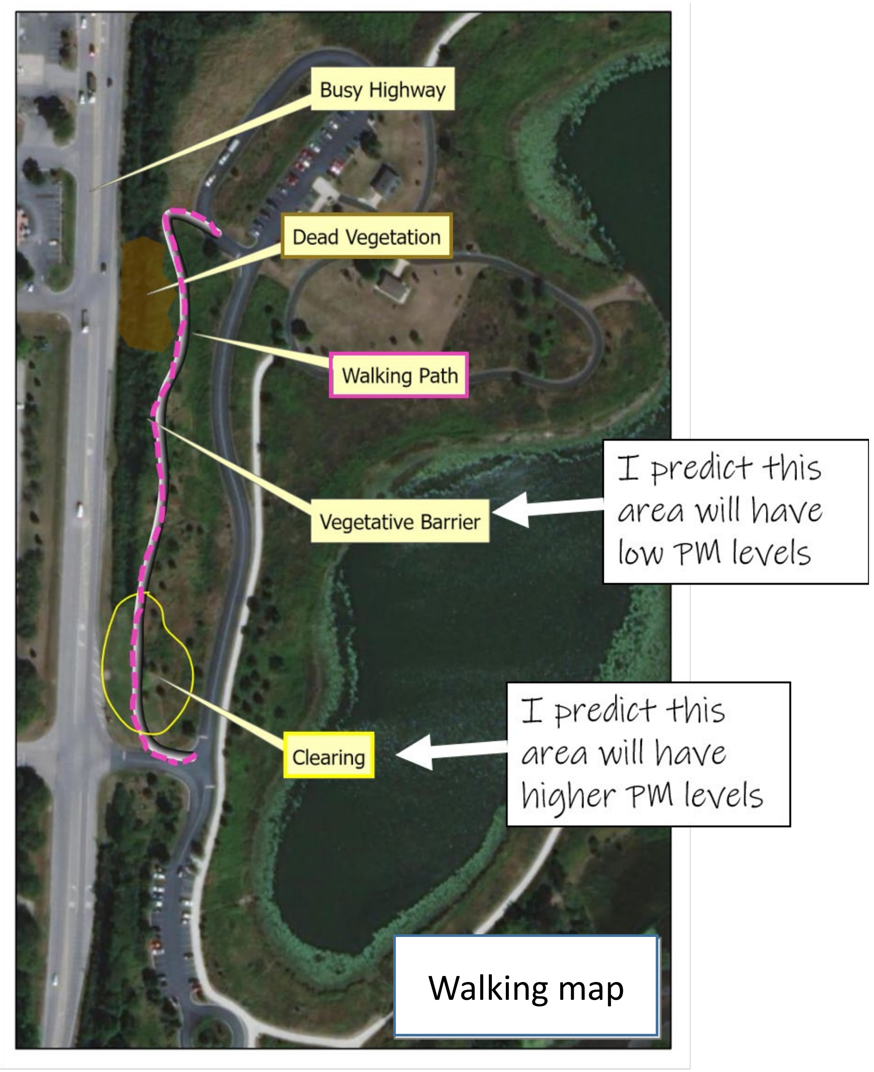
You will use online maps to find a vegetative barrier nearby that you can walk to

How to plan your route

- Identify and mark where a vegetative barrier may exist*
- Mark your walking route
- Make sure the path is **<u>safe</u>**

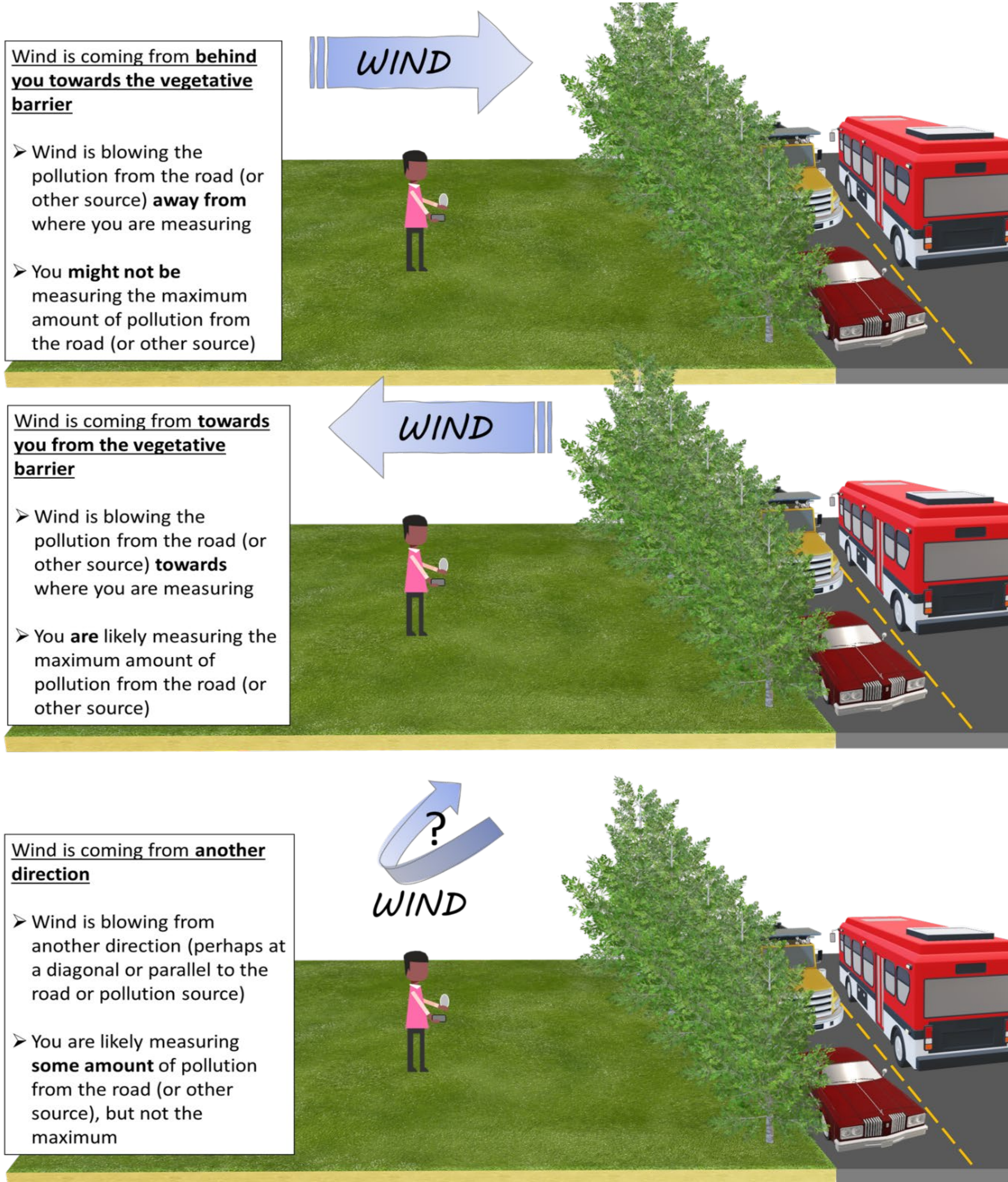
Mark areas you expect to have high and low PM **levels**

* If your community does not have a vegetative barrier, try walking to a **<u>safe</u>** location you think may benefit from a vegetative barrier



Understanding Wind Directions

- Understanding the direction of the wind and how that might influence your measurements is important in this lesson.
- The following graphic shows how wind direction can impact PM levels.



Tips:

AirCasting

Make sure your AirCasting session name is descriptive and appropriate!
It will be online and visible to the entire AirCasting community

Don’t cover the sensor air inlet or exit

10 ft

Keep the phone and sensor within 10 feet of each other

The AirBeam2 is water-resistant, not waterproof – make sure to protect the sensor in the rain (or snow) by using an umbrella

Make notes when you see high PM values

When you start recording, make sure that your GPS location is accurate

To use the belt clip to carry the AirBeam2, use the screw provided

Name:

Data Collection Worksheet

Date:

The Power of Plants! How Vegetation Can Help Protect Us from Air Pollution.

Pre-Activity Discussion Question

1 Can you think of any other benefits of vegetation?

Choose which of the two vegetative barriers in each set you think would be more effective and describe why.

2 The best option is:

3 The best option is:

4 The best option is:

5 To best protect the people who spend time at the recreation area, what characteristics would you want for the vegetative you would build between the recreation area and the busy road?

a. Length of barrier:

b. Depth/ thickness of barrier

c. Height of barrier

Name:

Data Collection Worksheet

Date:

5

d. Calculate the area of the barrier you would need (tip: area = length x depth)

e. Calculate the volume of the barrier you would need (*tip: volume = length x depth x height*):

f. If you are asked to plant trees that will grow to take up 5 meters in diameter when they are fully gown, how many trees would you need to cover the whole length of your barrier? *Tip: you can approximate the tree as a square where the sides are 5 meters in length*

6

Note the locations where you expect to find the highest and lowest $PM_{2.5}$ levels on your walk.

Highest	Lowest
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

Name:

Data Collection Worksheet

Date:

Observations

7

Use this section to take additional notes during your outdoor measurements.
Don’t forget that you can make notes and take photos on the app too!

8

BARRIER DESCRIPTION. Describe the visual characteristics of the barrier. How tall do you estimate it is? Are there gaps? Is it fully gown? Does it reach all the way to the ground?

9

WIND AND WEATHER. Note the weather conditions

Weather:

Wind direction:

Name:

Data Collection Worksheet

Date:

10 **BARRIER VS. NO BARRIER**. Take $PM_{2.5}$ measurements on both sides of the barrier.

$PM_{2.5}$ behind vegetative barrier (away from pollution source):

$PM_{2.5}$ past where the vegetative barrier ends:

Comment on the PM source. If the vegetative barrier is next to a road, is the road busy or quiet? Is it mostly trucks or passenger vehicles? If another PM pollution source, is that source operating?

11 **DISTANCE FROM BARRIER**. Make measurements at different distances **from the barrier**, moving away from the road and the vegetative barrier.

Distance from barrier	$PM_{2.5}$ level ($\mu g/m^3$)	Notes

Name:

Data Collection Worksheet

Date:

12

HEIGHT. If possible, try measuring at different heights up the barrier.

Height above ground	$PM_{2.5}$ level ($\mu g/m^3$)	Notes

13

GAPS. If you notice any gaps or changes in density of the barrier, measure PM in the gaps to see if your $PM_{2.5}$ values change.

Description of gap / change in vegetation	$PM_{2.5}$ level ($\mu g/m^3$)

Name:

Data Collection Worksheet

Date:

Interpret Your Data

14 What sources of $PM_{2.5}$ did you find on your walk?

15 What were the $PM_{2.5}$ levels you saw on your walking route? Were the levels what you expected them to be? Why or why not?

16 Where were $PM_{2.5}$ levels **highest**? Why do you think this was the case?

17 Did you collect data at multiple times of the day? Was one time at the same location higher than the other time(s)? Why do you think this was the case?

18 Where were $PM_{2.5}$ levels **lowest**? Why do you think this was the case?

Name:

Data Collection Worksheet

Date:

19 In each of the areas where you saw higher $PM_{2.5}$ levels, would it make sense to add a vegetative barrier there? Why or why not? Keep in mind any obstructions and the space available in the area for plants to grow.

20 Can you identify a location where it would be beneficial to add a vegetative barrier? Why did you choose this location?

21 Describe the characteristics you think would create an effective vegetative barrier in this area. How would a barrier in this location benefit the community? Were there houses, a park, school, or community center near the road?

Name:

Data Collection Worksheet

Date:

Interpret Your Vegetative Barrier Measurements

22 How did the $PM_{2.5}$ levels change when you measured at different heights up the barrier? Why do you think this is?

23 If you were able to measure at different distances away from the vegetative barrier, how did the $PM_{2.5}$ levels change as you got further away from the barrier? Why do you think that was the case?

24 Did you observe differences in $PM_{2.5}$ levels when you measured with and without a vegetative barrier? Explain your results and possible reasons for your observations.

25 How could the characteristics of the barrier have impacted the PM concentrations you measured?

Name:

Data Collection Worksheet

Date:

26 Overall, how effective was the vegetative barrier? Look back at the wind and other conditions you noted in bubble 9. How do you think the wind direction and weather could have played a role in your results?

27 If you could make changes to the vegetative barrier to improve it, what would you change and why?

Extra space for notes

Name:

Data Collection Worksheet

Date:

This page is provided in case you would like to create a graph by hand or make your own table.

O.S. Ryder, S.G. Brown, A.L. Clements, R.M. Duvall, S. Batka, M. Gavin. "The Power of Plants! How Vegetation Can Help Protect Us from Air Pollution", Air Sensor Loan Programs for Remote/Rural Locations and Living Museum, Funded by U.S. EPA, 2022

The Power of Plants! How Vegetation Can Help Protect Us from Air Pollution: **Instructor Answer Guide**

This document provides the answers to questions posed in the main lesson document.

Worksheet Box 1

Can you think of any other benefits of vegetation? Answers will vary but might include the aesthetic value of plants or sustainable farming of trees for wood.

Worksheet Boxes 2-4

In the section below, choose which of the two vegetative barriers in each set you think would be more effective and describe why.

2. **A**.
This is because option A has no gaps, the trees are tall and the foliage is full
3. **B**.
This is because option B has pine needles which help reduce PM more effectively than broader leaf species
4: **B**.
This is because option B shows tall hedges that reach to the ground and have no gaps. Option A has short hedges that would not provide much pollution production.

Worksheet Box 5

To best protect the people who spend time at the recreation area, what characteristics would you want for the vegetative barrier you would build between the recreation area and the busy road?

a. Length of barrier: 30 m + 50 m + 50 m = 130 m
b. Depth/thickness of barrier: at least 3 m
c. Height of barrier: at least 4 m
d. Calculate the area of the barrier you would need (tip: area = length x depth): 130 m * 3 m = 390 m^2 (will vary if another depth is chosen)
e. Calculate the volume of the barrier you would need (tip: volume = length x depth x height): 130 m * 3 m * 4 m = 1,560 m^3, but will vary if another depth or height was chosen
f. If you are asked to plant trees that will grow to take up 5 meters in diameter when they are fully gown, how many trees would you need to cover the whole **length** of your barrier? Tip: you can approximate the tree as a square where the sides are 5 meters in length. Would need 130/5 m to cover the length = 26 trees

Worksheet Box 6
Note the locations where you expect to find the highest and lowest $PM_{2.5}$ levels on your walk. Answers will vary. The highest levels will come from areas near sources. These might include busy roads with lots of truck traffic, ferry ports, construction sites, where agricultural equipment is frequently used, near quarries, and powerplants. Other sources of PM include burning activities such as wood appliances, fire pits, chimeneas, and backyard burn barrels, as well as where trash, leaves or wildfires are burning.

The lowest levels will likely occur in areas furthest from the above major sources, though wind strength and direction are also factors that may cause pollution to travel away from the source.

Worksheet Box 7
Use this section to take additional notes during your outdoor measurements. Don't forget that you can make notes and take photos on the app too. Answers will depend on location, time of day, etc.

Worksheet Box 8
Describe the visual characteristics of the barrier. How tall do you estimate it is? Are there gaps? Is it fully grown? Does it reach all the way to the ground? Answers will depend on the characteristics of the barrier.

Worksheet Box 9
What are the weather conditions during your measurement? Answers will depend on weather conditions but should include a description of the wind speed and direction.

Worksheet Box 10
Take $PM_{2.5}$ measurements on both sides of the barrier
- $PM_{2.5}$ behind vegetative barrier (away from pollution source): Answers should reflect measured $PM_{2.5}$ levels.
- $PM_{2.5}$ past where the vegetative barrier ends: Answers should reflect measured $PM_{2.5}$ levels.

Comments on the PM source. Answers will vary but should include observations of road and/or other PM source

Worksheet Box 11
Make measurements at different distances from the barrier, moving away from the road and vegetative barrier. Answers should reflect measured $PM_{2.5}$ levels.

Worksheet Box 12
Try measuring at different heights up the barrier. Answers should reflect measured $PM_{2.5}$ levels.

Worksheet Box 13

If you notice any gaps or changes in density of the barrier, measure PM in the gaps to see if your $PM_{2.5}$ values change. Answers will depend on measured $PM_{2.5}$ but should include a description of the gap or change in vegetation for each measurement.

Worksheet Box 14

What sources of $PM_{2.5}$ did you find on your walk? Many answers are possible (e.g., cars, trucks, construction, dust, etc.).

Worksheet Box 15

What were the $PM_{2.5}$ levels you saw on your walking route? Were the levels what you expected them to be? Why or why not? Any answer is OK as long as it is supported by the data.

Worksheet Box 16

Where were $PM_{2.5}$ levels highest? Why do you think this was the case? Answer will depend on data collected. As an example, the highest $PM_{2.5}$ levels were near the road because there were a lot of vehicles, which are a source of $PM_{2.5}$

Worksheet Box 17

Did you collect data at multiple times of the day? Was one time at the same location higher than the other time(s)? Why do you think this was the case? For multiple times of day collection, were there more vehicles due to increased traffic (i.e., rush hour, auto ferry or truck traffic increasing because of backups, school drop-off or pick-up, event activities, etc).

Worksheet Box 18

Where were $PM_{2.5}$ levels lowest? Why do you think this was the case? Answer will depend on data collected. May include weather (rain will lower $PM_{2.5}$ levels as it washes particles out of the air), it was a weekday with light traffic, auto shops were closed, the route chosen was in a residential neighborhood with little activity, on a day with calm/no wind.

Worksheet Box 19

In each of the areas where you saw higher $PM_{2.5}$ levels, would it make sense to add a vegetative barrier there? Why or why not? Keep in mind any obstructions and the space available in the area for plants to grow. Answer will depend on data collected and the area investigated. Vegetative barriers would be most effective in areas next to busy roads, or where a source of pollution exists near an area where people spend their time (e.g., a park, school, home, playground, etc.). Answers may also comment on whether there is room to install a vegetative barrier. Are there obstructions that might cause problems for the vegetation to grow?

Worksheet Box 20

Can you identify a location where it would be beneficial to add a vegetative barrier? Why did you choose this location? Answers will vary based on results, but might include locations next to busy roads, near places that experience higher diesel emissions, near parks, schools, or community centers, or around areas with other major sources of $PM_{2.5}$.

Suggested locations that might benefit from a vegetative barrier that might be in your area include:

1. A space adjacent to an interstate or major roadway that has space for a barrier.
2. A busy street that leads to an area which may have traffic congestion (i.e., border crossings, car entries onto ferries, special venues that host events which have large parking areas, etc.).

Worksheet Box 21

Describe the characteristics you think would create an effective vegetative barrier in this area. How would a barrier in this location benefit the community? Were there houses, a park, school, or community center near the road? Answers will vary based on the location of the proposed barrier. Characteristics of an effective vegetative barrier include that it is tall, thick, coniferous, native to the area, extends past the pollution source, and is easy for the community to maintain.

Worksheet Box 22

How did the $PM_{2.5}$ levels change when you measured at different heights up the barrier? Why do you think this is? Answers may vary based on the characteristics of the vegetative barrier and the heights used. If there were gaps or thinning, this may lead to higher levels at certain heights. If the barrier was short, this will also influence the measurements. For a uniform, healthy barrier, the PM values might be higher close to the top of the barrier, where the PM is no longer being filtered by the foliage.

Worksheet Box 23

If you were able to measure at different distances away from the vegetative barrier, how did the $PM_{2.5}$ levels change as you got further away from the barrier? Why do you think that was the case? Depending on how far from the barrier measurements were taken, answers will differ. $PM_{2.5}$ levels may decrease the further you get from the roadway. The rate of change may depend on wind speed, wind direction, and the direction students were moving. Measurements taken further away from the vegetative barrier may be higher, particularly if polluted air comes up and over the barrier, impacting areas further downwind.

Commented [PM1]: Missing the explanation of why the PM levels change.

Commented [CA2R1]: I added additional information to address your question. I'd like to give you a chance to re-review the added text for clarity.

Commented [PM3R1]: looks good!

Worksheet Box 24

Did you observe differences in $PM_{2.5}$ levels when you measured with and without a vegetative barrier? Explain your results and possible reasons for your observations. Answers will depend on data collected. Ideally, if the two locations differed only by the presence of a vegetative barrier, the $PM_{2.5}$ levels would be higher when no vegetative barrier was present.

Possible reasons that the ideal situation might not be observed:

- Differences in the $PM_{2.5}$ source: Measuring at different $PM_{2.5}$ sources may result in a difference in the amount of $PM_{2.5}$ produced (was one road busier than the other/was one source more active than another)
- Differences in wind direction: Whether measuring from the same source with and without a vegetative barrier, or from two different sources, the direction of the wind might influence the measurements. If the wind was blowing $PM_{2.5}$ from the source towards the participant in one instance but was blowing $PM_{2.5}$ away from the participant in the other instance, this might impact the levels observed.

- Measuring with and without a vegetative barrier from the same $PM_{2.5}$ source, but at different times of the day may influence the amount of $PM_{2.5}$ being produced.

Worksheet Box 25

How could the characteristics of the barrier have impacted the PM concentrations you measured? Barriers with gaps, barriers that do not reach the ground, and younger/less mature vegetation are likely to be less effective at filtering PM.

Worksheet Box 26

Overall, how effective was the vegetative barrier? How do you think the wind direction and weather could have played a role in your results? Answer will depend on the data collected. The vegetative barrier is expected to be more effective during high pollution periods. If the barrier had gaps, was thin, or exhibited other issues that prevent it from blocking and filtering PM, these factors may lead to a less effective barrier. Wind direction can influence how much variation is observed between measurements made at varying distances from the pollution source/roadway.

Worksheet Box 27

If you could make changes to the vegetative barrier to improve it, what would you change and why? Answer will depend on data collected. Ideas may include filling in gaps, creating a thicker barrier, switching the type of plant used, extending the barrier past the pollution source, or planting multiple layers of plants to bridge gaps that might exist near the ground.

Extension Activity

1. Describe the location you chose and explain the reasons you chose this location.
   Answers will vary but ideally would include a location that is distanced from major pollution sources. Alternatively, the selection may have been chosen based on ease of access for the community, or a centralized location on campus. Other considerations might include the amount of sun the location receives.

2. How does the location you chose rank in PM readings as compared to the other locations?
   Answers should reflect the PM data collected at the chosen locations.
   a. Did the different times of the day/days of the week change the PM readings between the locations?
   b. Often PM concentrations, especially near roadways, change throughout the day and over the course of the week. Higher concentrations are often observed during rush hour and weekdays when there is more traffic. Measurements taken at different times of day or on different days of the week may be influenced by changes in traffic patterns. Other influences include weather (e.g., rain or sunshine) and wind speed and direction.
   c. Has this review of all your PM readings changed your recommendations for siting a community garden?

Commented [PM4]: Is an answer missing here?

Commented [CA5R4]: An answer has been added for consistency.

Commented [PM6R4]: thumbs up!

If the chosen location ranked highest for PM vs. other locations, the participant may re-think whether this is the most desired location for the garden. In some cases, other factors, such as ease of access, may supersede the PM concern.

d. If it has not changed your recommendation, what might you do to reduce PM levels if the selected site has higher readings than the other locations?
   One option might be to plant a vegetative barrier around the community garden to protect it from PM sources.