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Vegetation Barrier Lesson Plans

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

ENVIRONMENTAL LAW & POLICY CENTER

Understanding Air Quality and Soil Quality at Your School Site

Project Overview for Educators

Trees, hedges, shrubs, and other green spaces provide a myriad of benefits to individuals, especially where people work, learn, live, and play. From improving physical and mental health, to increasing student's attention and test scores, to supporting vibrant ecosystems, the benefits of greening the landscape provide lasting impacts to community members and key stakeholders (see Turner-Skoff and Cavender, 2019). Perhaps one of the most important benefits that trees provide is removing pollution, which causes significant health issues. Urban and suburban settings are more susceptible to pollution and less likely to have vast expanses of green spaces to counteract these factors.

Schools and businesses adjacent to high traffic roadways are often subject to poor air and soil quality. Attempting to plant trees in soils of low quality will not solve the air quality issue as the trees will likely struggle and die before the buffer matures. Improving air and soil quality, especially near students or other vulnerable members of the population, is a critical human health issue. Vegetation barriers (trees/shrubs planted between the pollution source and the monitoring source) provide a mechanism to improve air and soil quality in these areas as the trees grow and develop over time.

The toolkit will support teachers and students as they conduct activities to understand what methods and species are the most successful at removing pollution. Their experiences and data collected will be used to help develop best practices that will be implemented at other schools around the country. The lesson sequence has been organized to allow teachers and students to understand air quality and make observations of air quality at their site, to understand how trees and vegetation can improve air quality over time, and to then develop mitigation plans and strategies that help improve these conditions. The document below outlines the education resources and components that would be part of this toolkit. The toolkit has been organized to provide schools and classrooms with tools to develop a vegetation barrier at their site, as well as monitor air quality, before and after installation.

NGSS-Aligned Standards

Grades 3-5

- **3-LS4-4**. Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.
- **3-5-ETS1-2**. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
- **5-ESS3-1**. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Grades 6-8

- **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-ESS3-3**. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.

- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

Grades 9-12

- **HS-LS2-5**. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- **HS-LS2-7**. Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- **HS-ESS3-4**. Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- **HS-ESS3-6**. Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.
- **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.

Select activities has also been aligned to Common Core Reading and Language Standards

- **RI.1**. Draw inferences from the text.
- **RI.2**. Determine the central idea or message of a text and supporting ideas.
- **RI.3**. Explain relationships, interactions, distinctions, and/or connections between ideas or concepts in a scientific text based on information or specific details in that text.
- **RI.4.** Determine the meaning of words or phrases in a text.
- **RI.10**. Read grade-level texts independently and proficiently.
- **L.4a**. Use context as a clue to the meaning of a word or phrase.
- **L.6.** Acquire and use accurately academic and domain-specific words and phrases.
- **SL.1**. Participate/engage effectively in collaborative group discussions.

Learning objectives

Students will be able to

- Trace pollutants (specifically air pollution) through the biosphere and geosphere.
- Understand the role of trees and their impacts to both the ecosystem as well as impact on human health.
- Generate ideas to mitigate air pollution in their community.
- Explore and analyze the health of their urban ecosystem, through data collection, monitoring, and investigation.
- Track and record air quality data for their surrounding school and school community. Data can be tracked over time from installation to subsequent years.
- Evaluate the success of the vegetation buffer on ecosystem services within their urban environment. (Evidence provided by monitoring data or other impact metrics, including community impact, school environment impact, etc.)

Curriculum outline and lesson progression

The lessons and activities outlined below are included as an appendix to this toolkit.

- **Setting the stage**
    - Introduction Activity: Anticipation Set - Find the Fiction - Air Quality Headlines Activity

    - Vocabulary Build: Vocabulary Story - Air Quality and Trees
- **Investigating the problem**
    - Observation: Measuring the Air Quality at Your Site: How to Use the Sensors, and Understanding Air Quality
        - Additional Resources: United States Environmental Protection Agency Air Sensor Loaning Resources
    - Connect: Trees,Shrubs and Air Quality - Science Notebook Activity
- **Designing a solution**
    - Action Planning Worksheet
    - Planning Your Vegetation Buffer
    - Investigating Soil on Your Schoolyard
    - Choosing the Trees for Your Barrier - Final Planning Activity
    - Bringing it All Together - Planting Design Proposal

Toolkit education loaning resources

In addition to the **Toolkit** and **Guides**, a bin of materials is available for loan to assist your site with implementing this type of project for your community. The bin contains a number of resources, equipment and monitoring tools to help your site create a vegetation barrier to reduce air pollution. Several of the activities and lessons included utilize these tools. The bin can be loaned for two weeks at a time and must be picked up from and returned to The Morton Arboretum. For more information visit https://mortonarb.org/educators/classroom-items-for-loan/.

Bin contents:

- Binder with printed toolkit and jump drive (digital content)
- Soil shovel (Qty: 5 per kit)
- Clipboard(s) (Qty: 5 per kit)
- Large tape measure (5 per kit)
- AirBeam2 sensor (EPA Loaning Resource - quantity determined by educators during toolkit registration)
- Mobile device for sensor (EPA Loaning Resource - quantity determined by educators during toolkit registration)

Please note: *This toolkit contains the AirBeam2 sensor, and there are some considerations to understand with use of this sensor. Current particulate matter (PM) air sensors (sensors) most effectively detect particles within the size range of about 0.5 - 2.5 microns (um) in diameter. However, research has shown (for example, Lin et al., 2016[1]) that vegetation is most effective at removing very small particles (called ultrafine particles, smaller than 0.1um) and larger particles (called coarse particles, larger than 2.5um), which fall outside of this optimal measurement range. Therefore, when using a PM sensor like the AirBeam2, we must realize that this sensor is not seeing the differences in the very small and larger particle concentrations, so we may likely not see the significant reductions in PM after the installation and maturation of a vegetative barrier using the AirBeam2 or other lower cost sensors. Additionally, it is important to note that vegetation barriers may take a few years to establish and demonstrate significant changes to air quality measurements. School sites should consider including and adopting additional mitigation strategies (outlined in the "Action Planning Worksheet - Air Quality and Vegetation Barrier" activity).*

[1] Lin, M.Y., Hagler, G., Baldauf, R., Isakov, V., Lin, H.Y. and Khlystov, A., 2016. The effects of vegetation barriers on near-road ultrafine particle number and carbon monoxide concentrations. *Science of the Total Environment*, 553, pp.372-379, https://doi.org/10.1016/j.scitotenv.2016.02.035.

Introduction Activity: Headline Sort

Background and activity overview

The activity below is designed as an introduction to air quality, air pollution, and trees' role in polluted environments. This activity is intended to be used at the beginning of the unit or discussion to activate student background knowledge and introduce them to concepts they will develop further.

Next Generation Science Standards

- **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
- **5-ESS3-1.** Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
- **MS-ESS3-3**. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **HS-LS2-5.** Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of a human activity on natural systems.

Common Core State Standards

- **RI.2**. Determine the central idea or message of a text and supporting ideas.
- **RI.3**. Explain relationships, interactions, distinctions, and/or connections between ideas or concepts in a scientific text based on information or specific details in that text.
- **SL.1**. Participate/engage effectively in collaborative group discussions.

Learning objectives

- To introduce students to concepts of air quality, air pollution, and trees' impact on these components.
- To read a series of statements and sort them by information type.

Materials

- One set of headlines per table/group
- One set of statements per table/group

Procedure

1. Introduce the three categories: What's in the Air, Air Pollution Sources, and Trees/Shrubs and Air Quality.
2. Explain to students that they will receive a series of statements. They need to discuss with their group which headline each statement belongs under and sort them accordingly.
3. Give the student 5-10 minutes to discuss and sort.
4. Review their thinking by reading each statement and asking the students which headline it belongs under and why. Statements might belong to one or more categories, so it is important to discuss the students' reasoning.

Headlines

- What's in the Air
- Air Pollution Sources and Air Quality
- Trees/Shrubs and Air Quality

Statements

- There are both natural and man-made causes of air pollution. Natural causes of air pollution include volcanoes, forest fires, and dust storms.
- A recent study found that trees remove some air pollution particles.
- The air quality index (AQI) is a daily report on how clean or polluted the air is. It includes what associated health effects might be a concern, especially for ground-level ozone and particle pollution.
- Particulate matter is a combination of liquid droplets and solid particles (like dust, smoke, and pollen) that are found in the air.
- Some particulate matter in the air is so small that it can only be seen with a microscope.
- Trees that have more hairs on the surface of their leaves do a better job of collecting air pollution particles from the air.
- Hazardous air pollutants can cause human health concerns such as cancer.
- Weather (rain, wind, and sunlight) impacts what is in the air. Rain often washes air pollution out of the air.
- Coniferous trees can capture more pollution over time because they do not lose their leaves in the winter.
- Man-made causes of air pollution include driving cars, burning fossil fuels, and burning wood as well as manufacturing and barbequing.
- Factories, highways, restaurants, and power plants can all be sources of air pollution within a community.
- Particulate matter (PM) in the air varies in size and is categorized as PM2.5 or PM10. PM10, the larger of the two sizes, is smaller than a grain of sand.
- Air pollution can make asthma symptoms worse. More than 6 million children in the United States have been diagnosed with asthma.

Cited sources

1. https://www.sciencemag.org/news/2010/10/tree-leaves-fight-pollution
2. https://www.nature.com/articles/s41598-017-03360-1.pdf
3. https://www.epa.gov/outdoor-air-quality-data/air-data-basic-information
4. https://www.epa.gov/sciencematters/links-between-air-pollution-and-childhood-asthma

Vocabulary Build:
Vocabulary Study–Air Quality and Trees

Background and activity overview

The activity below is designed as an introduction activity to expose students to specific science vocabulary that will be useful for the activities.

Next Generation Science Standards

- **5-ESS2-1**. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
- **5-ESS3-1**. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
- **MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.*
- **HS-LS2-5**. Develop a model to illustrate the role of photosynthesis and cellular respiration in the cycling of carbon among the biosphere, atmosphere, hydrosphere, and geosphere.
- **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.*

Common Core State Standards

- **RI.1**. Draw inferences from the text.
- **RI.4.** Determine the meaning of words or phrases in a text.
- **L.4a**. Use context as a clue to the meaning of a word or phrase.
- **L.6.** Acquire and accurately use academic and domain-specific words and phrases.

Learning objective

To practice using domain-specific vocabulary correctly by filling in the blanks in sentences of an informational text.

Materials

- Vocabulary story worksheet (one for each student)
- Answer key (attached)
- Writing utensil(s)
- Science notebook or notes
- Sticky notes or scrap paper (optional)
- Personal dry erase boards (optional)

Procedure

1. Begin the class with the following anticipatory set that sets the stage and piques the students' interest:
    a. Independently, have the students fill in the blanks in the following sentences by displaying them on the board: (NOTE: Do not offer a word bank during this activity.)
    b. A dog is a(n) ____; I know this because it only has sharp teeth, like a *Tyrannosaurus rex*. (carnivore)
    c. The _____ is a process in which water circulates, or cycles, through the lithosphere, biosphere, atmosphere, and hydrosphere; it is similar to the carbon cycle where carbon molecules cycle in and around the Earth. (water cycle)
    d. Trees, shrubs, flowers, and grass are ____, or plants, that produce their energy from the sun through a process called photosynthesis. (producers)
    e. Have the students share their responses. You might get different answers such as meat-eater, carnivore, carnivorous mammal, etc. Review these responses to see what they have in common.
2. Point out that there is more than one (context) clue in the sample sentences. For instance, in example (b), the first clue is that it only has sharp teeth, and the second clue compares it to *Tyrannosaurus rex*. Sometimes the clue can be a synonym, a definition, an example, or a comparison (point these out using the examples from the activity above). Explain that these clues are important when trying to understand a text.
3. Have students write their own context clue sentence with at least one or two clues. You can give them all one certain word they don't know, like "perfidious," or a vocabulary word to try this with and have them share their sentences aloud or with a partner.

Optional

- Give each student a scrap of paper or a sticky note.
- Display a list of words on the board or where the students can see them.
- Ask the students to choose one word from the list and write a context clue sentence, using their science notes, glossary, or dictionary if needed.
- Either read them aloud to the class and have the students guess the word by raising their hands or writing them on personal whiteboards, or distribute the student-made fill-in-the-blank sentences to the classroom and have them fill in the blanks and post them on the board or beside the given word on the board. This is a good informative assessment to gauge not only the class's understanding of the objective but also the individual student's.
- Tell the students that next they are going to read a story with several fill-in-the-blank examples. (NOTE: There are two versions attached: one with a word bank and one without for leveling.) Review the directions and expectations for this assignment. (OPTIONAL: Have students complete the vocabulary story worksheet in small groups or pairs, then challenge them to create their own vocabulary story as an assessment.)
- Give students time to complete the assignment independently.
- When completed, use one of the review activities listed below to go over the worksheet completely.

Review activities

- A fun way to review is to have the words in the word bank written on the board or where everyone can see them. Then read each sentence aloud and ask the students to write the word they think is correct on their personal dry erase boards and raise them into the air. This is a good quick assessment to see which students are exceeding, meeting, or struggling with the vocabulary.
- Play a “game show” by separating the class into two teams. Have one student from each team go to the “contestant table” where there is a buzzer. Read the sentence aloud and call on the first student who rings the buzzer to contribute the correct vocabulary word. Mix in older vocabulary words for review. (NOTE: This can translate well to a Kahoot! quiz for full class participation.)
- Keep a list of these words on display in the classroom on the board or on butcher paper. As students use these words naturally in class, put a tally mark by the word used. At the end of the week or unit, see which words were most used and which still need practice.

Discussion questions

- What context clues are most beneficial to you when trying to determine the meaning of a word? Why?
- Does every long or hard word have context clues when written in a text? Why or why not?
- Give an example of when having a context clue would have been beneficial for you.
- In what situations would context clues not be beneficial? Why not?
- Can context clues be something other than words (e.g. colors, shapes, symbols)? Explain your thinking.

Extensions

- Find articles in newspapers, magazines, or online texts with examples of context clues. Discuss why they are needed in that instance.
- Speak in context clues when giving directions (“When walking down the hallways, please stay on the starboard, or right-hand, side.”). Create a gesture to use (e.g., shoulder nudge or exaggerated wink) when using a context clue and encourage the students to do the same. (It’s so ridiculous that students will do it, just to make fun of it!)
- Highlight or underline the context clues in the text or an article the class is reading for another lesson.
- Watch a documentary such as “Planet Earth” and point out the context clues used in verbal communication. Discuss how it helps comprehension of the topic. Discuss why an easier or different word was not used instead.

Vocabulary story

Directions: Read the text below. Use the vocabulary words in the word bank to fill in the blanks in the text. Highlight or underline all the context clues (including ones not related to the words in the word bank).

particulate matter		air quality index	$PM_{2.5}$	PM_{10}
smog	air pollution		air quality	
	temperature inversion			

Take a deep breath, exhale, and think about the air you are breathing in. Although it seems like it's made of nothing, there is more in the air than you may realize. In addition to the oxygen you breathe and carbon dioxide that you exhale, the air contains water vapor and gases that have been added to the air by natural and man-made sources. When you think about _____ _____, you may think that the air would be dirty, but oftentimes air pollution is invisible.

Air pollution can be caused by natural processes, such as volcanoes, lightning, pollen, and forest fires. However, air pollution can also be caused by man-made actions, such as transportation, factories, restaurants, and the burning of fossil fuels (coal and oil). Forest fires create large amounts of smoke, and these particles are often trapped in the air. The exhaust from driving cars also emits pollution into the air. Both forest fires and vehicles release tiny substances known as _____ _____ into the air. Particulate matter varies in size and is smaller than a grain of sand. These particles are microscopic. If you think of a human hair, _____ is less than one-fifth the diameter of one hair. And _____ is even smaller than the diameter of 1 PM_{10}. Particulate matter can reduce visibility in the air. This haze, known as _____ , was named by combining the words “smoke” and “fog.”

Although PM_{10} and $PM_{2.5}$ are incredibly tiny, they are mighty. These small particles can have great impacts on human health if their quantity increases in the air we breathe. To understand the risk to human health, we can measure air pollution by understanding _____ _____. If we want to know how much air pollution is in the air, we measure air quality, using the _____ _____ _____. These color-coded values and ratings break down the overall health risk and estimated amount of air pollution on a given day. The air quality index, or AQI, has a range from good to hazardous, or green to maroon.

A number of factors impact air pollution. Because weather is responsible for moving the air in our lower atmosphere, weather and temperature can impact air quality. Sunlight adds heat energy into the atmosphere and can result in more chemical reactions that increase air pollution. However, rain often washes particulate matter out of the air for brief periods of time. Changes in temperature often influence weather patterns. When warm air is sandwiched between two cool layers of air, the pollution in the lower layer is trapped near the Earth’s surface. This is called a _____ _____.

Because air pollution can impact our lungs, heart, and overall health, it is important to monitor how our actions affect the air around us and to think about ways in which we can strive to reduce emissions while we also work to eliminate them from the air.

Vocabulary story – answer key

Directions: Read the text below. Use the vocabulary words in the word bank to fill in the blanks of the text. Highlight or underline all the context clues (including ones not related to the words in the word bank).

particulate matter air quality index $PM_{2.5}$ PM_{10}
smog air pollution air quality
temperature inversion

Take a deep breath, exhale, and think about the air you are breathing in. Although it seems like it's made of nothing, there is more in the air than you may realize. In addition to the oxygen you breathe and carbon dioxide that you exhale, the air contains water vapor and gases that have been added to the air by natural and man-made sources. When you think about air pollution, you may think that the air would be dirty, but oftentimes air pollution is invisible.

Air pollution can be caused by natural processes, such as volcanoes, lightning, pollen, and forest fires. However, air pollution can also be caused by man-made actions, such as transportation, factories, restaurants, and the burning of fossil fuels (coal and oil). Forest fires create large amounts of smoke, and these particles are often trapped in the air. The exhaust from driving cars also emits pollution into the air. Both forest fires and vehicles release tiny substances known as particulate matter into the air. Particulate matter varies in size and is smaller than a grain of sand. These particles are microscopic. If you think of a human hair, PM_{10} is less than one-fifth the diameter of one hair. And $PM_{2.5}$ is even smaller than the diameter of 1 PM_{10}. Particulate matter can reduce visibility in the air. This haze, known as smog , was named by combining the words “smoke” and “fog.”

Although PM_{10} and $PM_{2.5}$ are incredibly tiny, they are mighty. These small particles can have great impacts on human health if their quantity increases in the air we breathe. To understand the risk to human health, we can measure air pollution by understanding air quality. If we want to know how much air pollution is in the air, we measure air quality, using the air quality index. These color-coded values and ratings break down the overall health risk and estimated amount of air pollution on a given day. The air quality index, or AQI, has a range from good to hazardous, or green to maroon.

A number of factors impact air pollution. Because weather is responsible for moving the air in our lower atmosphere, weather and temperature can impact air quality., Sunlight adds heat energy into the atmosphere and can result in more chemical reactions that increase air pollution. However, rain often washes particulate matter out of the air for brief periods of time. Changes in temperature often influence weather patterns. When warm air is sandwiched between two cool layers of air, the pollution in the lower layer is trapped near the Earth’s surface. This is called a temperature inversion.

Because air pollution can impact our lungs, heart, and overall health, it is important to monitor how our actions affect the air around us and to think about ways in which we can strive to reduce emissions while we also work to eliminate them from the air.

Vocabulary story definitions

Air pollution:

_____

_____

Particulate matter:

_____

_____

PM_{10}:

_____

_____

$PM_{2.5}$:

_____

_____

Smog:

_____

_____

Air quality:

_____

_____

Air quality index:

_____

_____

Temperature inversion:

_____

_____

Observation - Understanding and Measuring Air Quality at Your Site

Background and activity overview

In this activity, students will understand the impacts of air quality on their school community. They will spend time outside taking air quality measurements using an air quality sensor. This lesson/activity may take a few days or sessions to complete. Additionally, there are some details that would need to be created by teachers/educators to make the activity specific to your site/community.

Next Generation Science Standards

- **5-ESS2-1.** Develop a model using an example to describe ways in which the geosphere, biosphere, hydrosphere, and/or atmosphere interact.
- **MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.

Learning objectives

- Students will generate ideas to mitigate air pollution in their community.
- Students will be able to explore and analyze the health of their urban ecosystem through data collection, monitoring, and investigation.
- Students will track and record air quality data for their school and surrounding community. Data can be tracked over time from installation to subsequent years.

Resources and materials

- One AirBeam2 sensor (from toolkit) per student group or class
- One mobile device (from toolkit) per student group or class
- Clipboards (from toolkit)
- Writing utensil(s)
- One air quality data sheet per student or group
- Printed/digital resources from U.S. EPA's Air Sensor Toolbox Educational Resource "What Is in the Outdoor Air? Exploring Particulate Matter (PM) Sources and Air Quality Outdoors" (U.S. EPA's Outdoor Air Lesson)
- Supplement 1 (Page 17 of this document) - Example map for walking path

Procedure

Part 1: Air quality/pollution discussion and map analysis

Teachers note: The activity outlined below is adapted from the U.S. EPA's Outdoor Air Lesson, which is part of the air quality loaning resource. A full activity outline is included in the Vegetation Barrier Toolkit, as both a digital and printed resource in this toolkit. To get started, review pages i-iv of this document (Outdoor Air Lesson/Activity). This is the instructor guide section. More information is available in the appendix section of this document. A printed copy of the Outdoor Air Lesson/Activity is also included in the toolkit binder and loaning resource.

1. Begin by asking students what they think about the air they breathe outside of the school. Activate their background knowledge regarding air quality and air pollution from the introduction activities.
2. Ask students, What questions do you have about the air quality in our community? Do you think it would be healthy? Why or why not? How can we investigate the answer to these questions?
3. Review some Air Quality 101 information with students. Included below are some video links to introduce air quality concepts:
    a. https://www.youtube.com/watch?v=e6rglsLy1Ys
    b. https://www.youtube.com/watch?v=Tds3k97aAzo
4. Based on this content review, ask, Where could pollution in your community come from? Where do you want to measure air quality in your community? Outline to students the sources of $PM_{2.5}$, as this will be one of the measurements recorded using the AirBeam2 sensor.
5. Teachers note: For the next portion of the discussion you will need to generate a map (using Google Maps) of your community and the areas around your school. You will need to drop this map into the Air Quality in Your Community data sheet so that this resource is specific to the area where you plan to take measurements. Additionally, after the students have identified potential pollution sources, you should draw the route you plan to take when collecting air quality measurements. (For additional reference, use pages 9-10 in the Outdoor Air Lesson activity, printed in this toolkit and available digitally). Sample maps have been included in this lesson.
6. Using the Air Quality in Your Community data sheet, have students place a star on places that may be a source of air pollution.
7. Next, discuss with students the route you will take to measure air quality. Optional: Students can develop a walking route for your data collection, based on the sources of air pollution they identified on their maps. To ensure student safety, however, teachers should collaborate with students to decide the safest options possible, given the school community and existing traffic. Additional safety measures may need to be taken, and students should avoid high-traffic expressways or roadways.

Part 2: Taking air quality measurements:

Teachers note: Prior to class/session, set up the AirBeam2 sensors and create an account for recording your data. The toolkit contains the following resources to help you set up the sensors and their accompanying mobile devices. You will need to be connected to the internet for the setup of the devices. However, you do not need to be connected to the internet to cast air quality measurements. The mobile device receives the air quality data via Bluetooth from the AirBeam2 sensor. Review pages 11-12 of the Outdoor Air Activity/Lesson for additional details on data collection.

- AirBeam Instructional Video (from U.S. EPA)
- AirBeam2 Quickstart Guide (from U.S. EPA) (Printed copy also included in the toolkit binder and loaning resource.

1. After you have set up the sensors and are ready to record data, outline your expectations to students for recording air quality data outside during the walk. Additionally, if applicable, use the data observation sheet included in this activity. Please note: These observations can also be recorded in the Air Casting application. Choose which observation procedure best fits your students. (NOTE: Consider encouraging the class to take about 5 minutes of data with all their sensors together to understand how well their sensors compare. This is an opportunity for them to interpret their data and understand that the technology needs to be monitored and used properly in order to collect correct/accurate data.)
2. After you have recorded data in the Air Casting application, use the AirBeam2 sensor to review the data to understand your recorded readings. (Review pages 13-14 of the Outdoor Air Activity/Lesson). Using their readings, have students complete the Interpret Observations section of the data collection worksheet.

3. Discuss results as a class. Please note: Air quality measurements are influenced by weather, temperature, and time of day, based on activities that occur in your community. Consider having students record air quality measurements a few times over the course of a week or so and compare the results.
4. Please note: This toolkit contains the AirBeam2 sensor, and there are some considerations to understand with use of this sensor. Particulate matter (PM) is most effectively detected within the size range of about 0.5-2.5 microns (um) in diameter. However, research has shown (for example, Lin, et al., 2016) that vegetation is most effective at removing very small particles (called ultrafine particles, smaller than 0.1um) and larger particles (called coarse particles, larger than 2.5um) which fall outside this optimal measurement range. Therefore, when using a PM sensor like the AirBeam2, we must realize that this sensor is not seeing the differences in the very small and larger particle concentrations, so we may likely not see the significant reductions in PM after the installation and maturation of a vegetative barrier using the Airbeam2 or other lower-cost sensors. Additionally, it is important to note that vegetation barriers may take a few years to establish and demonstrate significant changes to air quality measurements. School sites should consider including and adopting additional mitigation strategies (outlined in the Action Planning Worksheet - Air Quality and Vegetation Barrier activity).

Air Quality in Your Community - Data Sheet

Part 1: Community predictions

Directions: Look at the map of your community (pasted below). Based on our discussion about air pollution sources and human activities that contribute to air pollution, where do you think potential sources of air pollution may be in your community? Answer the questions after you have reviewed your map.

(Insert Google Map or community map)

Where do you think you will find $PM_{2.5}$ sources on your walk?

Based on your air quality discussions, what time of day do you think would most impact your observations?

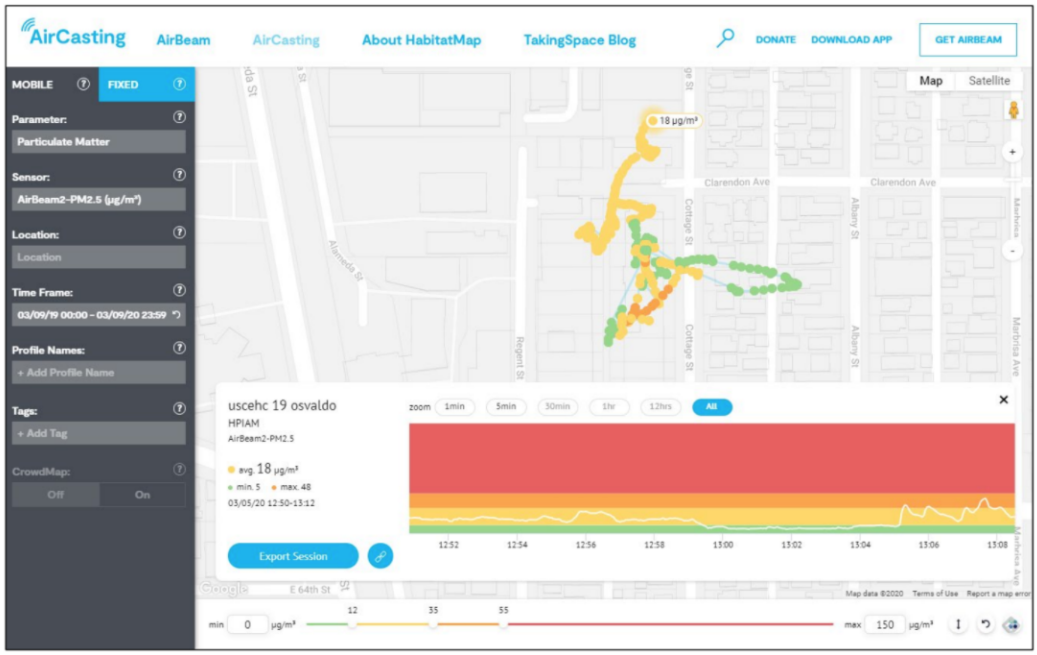
Part 2: Air quality walk observations/measurements

Directions: While using the AirBeam2 sensor, record observations of things you notice that may contribute to your air quality readings. Please note: You can also make these observations (photo and written) in the AirCasting application.

Use the box below to record your observations. (Be sure to describe your location with your observation.)

Part 3: Understand your measurements

Directions: Review the data you collected in the AirCasting application. You can also find the data you recorded during your walk from the AirCasting website. See example below (excerpt from Outdoor Air Activity—EPA Air Quality Monitoring Resource included in this toolkit).



Based on your measurements and observations, answer the questions below.

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

- Did you find any sources of $PM_{2.5}$ that you did not expect?

- Did you notice any obstacles or structures that could block air movement? If yes, describe them.

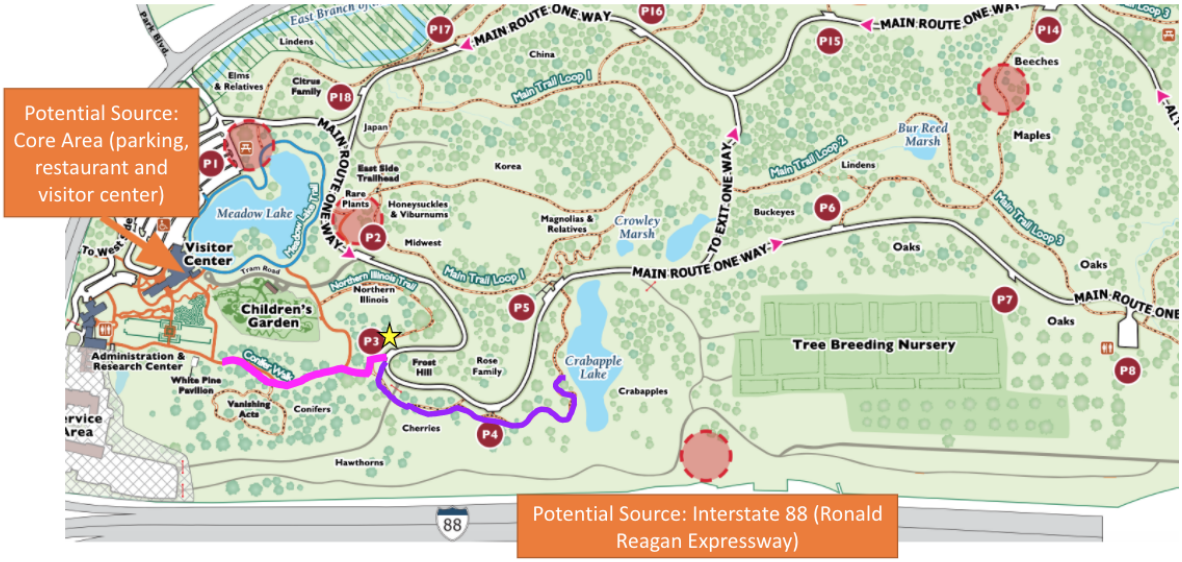
- What were the weather conditions like during your walk?

- Where was $PM_{2.5}$ the highest? Was this what you expected? Why do you think this was the case?

- Where was $PM_{2.5}$ the lowest? Was this what you expected? Why do you think this was the case?

- In places where you saw higher levels of $PM_{2.5}$, what do you think could be done to reduce this measurement?

Supplement 1: Sample Walking Map (linked slide show)



Part 1: Readings in the Conifer

(This route is .26miles round trip)

- From this lot, find the wood-chipped trail that will be located, straight and slightly to the left of the pull-off parking area.
- Once you find the trail, make a right and head down towards a paved path.
- Use the Air Beam sensor to take readings in this area, known as the conifer collection. This area contains needle bearing trees from around the world.
- Once you have reached the trail juncture for the remainder of the conifer trail, turn around and head back to the lot where you were parked.

Part 2: Readings in the cherries/crabapples

(This route is .38miles round trip)

- From the parking lot, walk in the opposite direction of the conifers, you just visited.
- Find the wood chipped path, this will follow adjacent to the road you drove in on, but away from the visitor center core area.
- Use the Air Beam sensor to take readings in this area, where cherry and Crab Apple trees are present. Once you have reached the picnic bench with a apple over top, turn around and head pack to parking lot 3.

Connect: Trees, Shrubs, and Air Quality - Interactive Science Notebook Strategy

Background and activity overview

This activity is intended to help students investigate how trees can impact air quality. The strategy outlined below (interactive science notebook), provides space for them to conduct research and answer questions about articles or other media they are using to answer the proposed question. The concept behind interactive science notebooks is to provide a space for students to practice scientific habits of mind by recording observations, questions, and mind maps. These writings and entries help to deepen their understanding of scientific concepts and phenomena.

Interactive science notebooks become a way for students to demonstrate their understanding by making connections and thinking through the scientific process. Additionally, they help students to organize their thoughts and think out loud (write out loud) to reinforce their learning.

Science notebooks can be organized in a number of different formats and can be utilized at different times in your unit. A few critical components are helpful to consider:.

> **Date and title for each entry:** Helps reinforce organization and sequential student thinking. Over time, this will also demonstrate student constructs of knowledge and progression of understanding.
>
> **Input section:** Notes, vocabulary, and concepts. This section contains information that is GIVEN to students. This can include lecture notes, video notes, lab activities or procedures, vocabulary lists/definitions, or any other information that is provided to students. This section may be similar among students.
>
> **Output section:** Creativity, questions, additional observations, brainstorming, and pictures. This section should vary from student to student and provide space for students to develop their understanding of the content that has been given to them: What questions do they have? Can they draw or illustrate their understanding of the concept? Can they create a mind map, diagram, or flowchart to summarize the information or process?

Note about modifying for digital notebook: Students can create a science notebook in online or software word processing applications. The main-page document serves as the right side of the notebook. Students can utilize comments or insert links to add their own content and connections that you would usually fill in on the left side of the page.

Next Generation Science Standards

- **5-ESS3-1**. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.
- **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-ESS3-3**. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **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.

Common Core State Standards

- **RI1.** Use textual evidence to explain what the text says.
- **RI2.** Summarize the text.
- **RI.10**. Read grade-level texts independently and proficiently.
- **L.4**. Determine the meaning of unknown words and phrases in a text.
- **L.6**. Acquire and use accurate general academic and domain-specific words.

Learning objectives

- Students will be able to read grade-level non-fiction texts and construct meaning, connected to their background knowledge.
- Students will be able to map their understanding of how trees and air quality are connected based on Earth systems and biological processes present in the environment.

Resources and materials

- Web links to articles/videos or printed copies of articles related to air quality and trees. (included links below)
    - Planting Cleaner Air: Can Roadside Plants Reduce Air Pollution?
    - The Best Trees to Reduce Air Pollution
    - Trees Please (Best suited for grades 5-8)
    - Video from 1 Trillion Trees: https://www.youtube.com/watch?v=XVUAgcSCP_U
- Science Notebook Article Analysis Worksheet (1 per student) - pages 21-22 of this document.
- Writing utensil(s)

Procedure

1. For this activity example, the science notebook strategy will be used when reading articles on air pollution and trees.
2. Begin by choosing an article for your students to investigate. The content and readability for each article varies, so you can choose the article that is the best fit for your group or assign articles to groups of students and then synthesize their findings as a jigsaw activity (in which students discuss their findings from their article, but each student has a different article to share).
    a. Planting Cleaner Air: Can Roadside Plants Reduce Air Pollution?
    b. The Best Trees to Reduce Air Pollution
    c. Trees Please (Best suited for grades 5-8)
    d. Video from 1 Trillion Trees: https://www.youtube.com/watch?v=XVUAgcSCP_U
3. Students will complete the right-hand side of the notebook/organizer during the first or second reading of the article and then make connections to the content on the left side (output) of the organizer. They can choose the "how" for the left side (output), but the goal is to allow space and the opportunity for students to connect this content to their prior knowledge and think aloud (or through illustration) about what they are learning.
    - Have students download the science notebook template. Note: If students are working remotely, copy and paste this template into a google doc or preferred platform.
    - **Right side:** Have students read one of the selected articles independently and complete the right side of the template.
    - **Left-side options:** Students can choose among the following options to complete the left side of the template:

- This reminds me of ….. (T-chart): For each statement/answer, students complete the sentence stem, “This reminds me of…”
    i.

Statement/fact from the video (question/answer)	Finish this sentence for each fact/video answer… (This reminds me of…)

- Mind map illustration (drawing): Students use the terms and facts they recorded from the right side to connect or group the items in a way that makes sense to them. The following questions can help to guide them in their mind map creation:
    i. Are any of these terms/words PART of another term?
    ii. Do any of these terms seem to be PART of the same system?
    iii. Do any of these terms seem to be OPPOSITE?
    iv. Do any of these terms relate to other terms/words you have learned before?
- Simile illustration: Using one of the visuals from the article, students create their own illustration or photo representation comparing the video visual to their illustration. They must, however, indicate WHY their illustration is like the video visual.
    i. For example: In the articles, the visuals of the leaf could be compared to a solar panel. A leaf is like a solar panel BECAUSE… it collects light energy from the sun.
    ii. Note: **To adapt for remote learning**, have students link images they have created in drawings or Google slides.

Science Notebook - Article Analysis Worksheet

Output: Left side of the notebook (complete second)	Input: Right side of notebook (complete first)
Directions: *Choose among the following options to complete the left side of the template:* ● ***This reminds me of … (T-chart)*** ● ***Mind map illustration (drawing)****: Use the terms and facts students recorded from the right side to connect or group the items in a way that makes sense to your group. The following questions can help to guide you in your mind map creation:* ○ *Are any of these terms/words PART of another term?* ○ *Do any of these terms seem to be PART of the same system?* ○ *Do any of these terms seem to be OPPOSITE?* ○ *Do any of these terms relate to other terms/words you have learned before?* ● ***Simile illustration:*** *Using one of the visuals from the video, create your own illustration or photo representation comparing the video visual to your illustration. You must indicate WHY your illustration is like the video visual.* ○ *For example: In the photosynthesis video, the visuals of the leaf could be compared to a solar panel. A leaf is like a solar panel BECAUSE… it collects light energy from the sun.*	***Directions****: Choose one of the linked science articles. As you read, record your notes and questions that you have.* *You may need to read the article more than once. After your first read, review the listed questions before reading the article a second time and answering the questions in Part 2.*
	Part 1(notes and questions): *Write a one-sentence summary of the article.* *Write three supporting details that connect to your summary statement.* *Record two facts that you found most interesting.*

	Part 2 (questions to answer to check understanding): *Describe how the article connects trees and air pollution.* *What impact does planting trees have on air quality over time?* *How does this information make you think about your school community and the air quality readings you collected earlier?*

Action Planning Worksheet – Air Quality and Vegetation Barrier

Background information/activity overview

In this activity, students will synthesize the information and measurements they have collected on the air quality in their community. Based on this data, they will make a goal and action plan to determine how to improve their air quality.

Next Generation Science Standards

- **3-LS4-4.** Make a claim about the merit of a solution to a problem caused when the environment changes and the types of plants and animals that live there may change.
- **3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **MS-ESS3-3**. Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **HS-LS2-7.** Design, evaluate, and refine a solution for reducing the impacts of human activities on the environment and biodiversity.
- **HS-ESS3-4.** Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.
- **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.

Learning objectives

- Students will be able to determine an achievable goal to improve the air quality in their school or community setting.
- Students will develop action steps to accomplish their air quality improvement goal.

Materials

- Air quality measurements taken using the AirBeam2 sensor
- Science notebook observations/notes
- Copy of the goal and action step organizer (one per student/group)
- Writing utensil(s)
- Resources:
    - EPA's Best Practices for Reducing Near-Road Pollution at Schools
    - Idle-Free Schools Toolkit for a Healthy School Environment
    - Air Quality Flag Program.

Procedure:

1. Ask students how they believe they can impact air quality at their school site. Based on what they have observed thus far, have them brainstorm in groups to come up with solutions.
2. Review the additional resources for mitigating air pollution at your school. (Best Practices for Reducing Near-Road Pollution at Schools, Idle-Free Schools Toolkit for a Healthy School Environment, and Air Flag Program.)
3. Each group of students should complete the action step organizer.
4. Assist students in thinking about sources of air pollution within their school community as well as methods of reducing air pollution.
5. During their brainstorm, lead students to consider utilizing vegetation on their site to reduce air pollution. Ask students the following questions to help them develop action steps that can be implemented in the next phase of this project.
    a. What have you learned that helps to reduce air pollution?
    b. Where should we consider planting, based on sources of air pollution in our community? How much room do we have? How much room do we need?
    c. What do we need to do to the site/ground/area in order to plant trees/shrubs?
    d. What trees/plants should we choose to plant?
6. After students have drafted their action steps, have them share their ideas as a group.
7. As a class, develop a plan to implement a series of action steps. Utilize the subsequent activities in this toolkit to plan your vegetation barrier.

Goal and actionstep organizer

Set a goal
As a group, brainstorm some ideas and then decide on a goal you want to accomplish to improve, add to, or impact the air quality in your community.

Goal:

Action steps
What are your next steps? What do you need to do to accomplish this goal? What materials will you need? How long do you think it will take? Use the organizer below to lay out your action steps and timeline.

Action steps	**Materials/resources** *What materials will you need to complete this step?* *What resources or information do you need to gather to complete this step?*	**Timeline** *How long will it take to complete this step?*

Planning Your Vegetation Barrier

Background and activity overview

In this activity, students will make a proposed map of their site to identify where to plant a vegetation barrier to mitigate air pollution.

Next Generation Science Standards

- **3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **MS-LS2-5.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- **MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **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.

Learning objectives

- Students will develop a planting design to mitigate air pollution at their site and improve air quality.
- Students will identify important features and components of vegetation barriers to help them propose a planting design at their site.
- Students will evaluate their proposed planting site, using a data set criteria.

Materials:

- Power of Plants Lesson Plan/Activity form EPA's Air Quality Loaning Resource.
- Map of community or access to Google Maps
- Site Evaluation Data Sheet (1 per group of students)
- Clipboards
- Writing utensil(s)

Procedure:

Part 1: Understanding vegetation barriers

1. To plan your vegetation barrier, use the Power of Plants activity from the EPA's Air Quality Loaning Resource. This resource can also be found in the Appendix section of the vegetation barrier lesson plans.
2. This lesson identifies some key characteristics of vegetation barriers that help them mitigate air pollution. These factors include tree species (conifer or deciduous), height, and proximity to the pollution source as well as spacing/gaps between trees or shrubs in the planting. This activity encourages students to evaluate the air quality near a vegetation barrier using the AirBeam2 sensor. Using the first sections of this activity to help students understand how to identify vegetation barriers in your community may help students plan their own.
3. Next, students will first need to propose a location for the vegetation barrier on their school site. Using Google Maps, students can create custom maps identifying their proposed barrier plot.

Part 2: Mapping your site

1. This activity can be done as a class or in cooperative learning groups.
2. Begin by having students open a web browser and open Google Maps.
3. On the left-hand side toolbar, select “Your Places.”
4. Along the top of the window, select “Maps.”
5. A new window will open and they will be Zoomed out of their current location. Have them name their map by selecting “Untitled.”
6. Next, type the address of the school into the box in the middle of the screen.
7. Find the toolbar (pictured right). Using the line and pin icons, students can draw their proposed plot and where they think trees would be best to include in the barrier. Additionally they can use the ruler icon in this toolbar to measure distances.

Part 3: Outside evaluation of your proposed planting site

1. After students have a proposed map drawn in Google Maps, they can print this map and head outside to evaluate their proposed location. Use the Site Evaluation Data Sheet for this next section.
2. Students should take with them a tape measure and clipboard in addition to their map and data sheet.
3. Be sure to consider all safety precautions when taking students outdoors. Set guidelines and expectations for students to avoid high-traffic areas, be alert, and stay together as a class.

Part 4: Analysis of your proposed vegetation barrier site

1. As a class, review your group data sheets.
2. Ask students, Did anyone have to answer “yes” to the last column of the data sheet? If so, this proposed location may not be the best fit for a vegetation barrier planting.
3. Review each group’s map and select the top candidate for a planting site. Next, students will need to update their action plan for this project.
4. Ask students to add to their action plan (previous activity) as you consider the additional following needs for this planting project:
    a. Where is the nearest source of water?
    b. Will the barrier obstruct visibility in an area regularly used by people?
    c. Are there places on the ground where no plants are growing and there is only bare soil? What do you think needs to be done to test or check the soil quality for this planting?

Site Evaluation Data Sheet

Amount of **sunlight** for planting area	❏ Full sunlight – more than 6 hours of direct sunlight ❏ Partial shade – 4 to 6 hours of direct sunlight ❏ Full shade – less than 4 hours of direct sunlight	Is the planting site in full shade?	❏ Yes ❏ No
Length and width of **planting area**	Length: _____ feet Width: _____ feet	Is the planting area width <u>less than</u> 30 feet?	❏ Yes ❏ No
Distance from planting area to nearest **buildings and pavement** (hardscape). Check multiple directions.	_____ feet _____ feet	Is there hardscape less than 16 feet in multiple directions from the planting area?	❏ Yes ❏ No
Location of **overhead utility lines** on property	Notes:	Are there utility wires above the planting site?	❏ Yes ❏ No
Distance from planting area to **underground utilities**	Find out if there are underground utilities, and if so, work with your facilities to understand this potential hazard. If they are able to identify these lines for you, determine distances to where you plan on planting. _____ feet from buried utilities	Is there buried infrastructure within 10 feet of your planting area?	❏ Yes ❏ No
Distance to nearest **sidewalk or road**	_____ feet	Are there sidewalks, roads, or other pavement within 10 feet of the planting area?	❏ Yes ❏ No
The planting site is on…	❏ Flat ground ❏ The top of a hill ❏ A low-lying area that sometimes holds water	Is the planting area in a low-lying area that is sometimes filled with water or puddles?	❏ Yes ❏ No

(Also available in Vegetation Barrier Toolkit pages 51-52 -Field Sheet #2)

- What type of plants are growing at the site? If quality mature trees are already present, you may need to adjust your barrier design to protect these trees.

Investigating Soil on Your Schoolyard

Background and activity overview

In this activity, students will analyze and investigate the soil quality in the area they are proposing for a vegetation barrier. This activity has been modified for students by using the Vegetation Barrier Planting Guide #3 - Getting to Know Your Soil, included in this toolkit. Because components of this activity will take place outside, additional considerations should be taken to ensure student safety.

Next Generation Science Standards

- **3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **MS-LS2-5.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- **MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **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.

Learning objectives

- Students will identify their soil quality and soil type.
- Students will identify if any adjustments need to be made to improve the soil at their site to ensure healthy vegetation.
- Students will continue their design solution to improve the air quality in their community through the installation of vegetation near pollution sources (roadways).

Materials

- One hand shovel per group of students
- Two 3-gallon zip-sealing plastic bags for soil samples per group of students
- Measuring tape
- One small pipette per group of students
- One plastic knife per group of students
- Soil Testing Data Sheet (1 per group)
- Clipboards (1 per group)
- Guide #5 - Get to know your soil (pgs 17-23 of the Vegetation Barrier Toolkit)

Procedure

1. After you have determined where you may want to plant your vegetation barrier, you should determine a few places to test the soil in this area. Consider testing four to 10 spots based on your site and the size of the barrier you want to install.
2. You can have students work in cooperative learning groups and assign each group a testing area or test each area as a whole class. Consider modeling each test as a group before allowing student groups independent time to conduct the tests.
3. Create a map of your site and determine testing areas. Distribute these to students to use alongside their data sheets.
4. Acquire materials (clipboards, soil probes, data sheets, and sample bags) and take students outside. Consider all safety precautions when taking students outdoors for this lesson (traffic, group spacing, etc.)
5. **Please note:** A detailed overview of soil testing and understanding soil is included in the Vegetation Toolkit **Guide #5: Get to Know your Soil**, pages 17-23. Because testing soil drainage and soil pH may be challenging to complete in a traditional class-period length, consider doing this ahead of time or ask maintenance staff assisting with this project to test the soil drainage and pH beforehand. In this activity, students are identifying the characteristics of the soil in their proposed plot as well as measuring the degree of soil compaction. The entire soil section of the planting guide should be considered before finalizing the vegetation barrier planting plan.
6. Once outdoors, assign student(s)/student groups to a testing location. Be sure they have a hand shovel, clipboard, data sheet, and sealable sample bags available.
7. Demonstrate to students how to use a hand shovel and obtain a sample that they can use for indoor soil tests.
8. Students should divide the sample they take into two bags to account for the two soil tests they will complete indoors.
9. While outdoors, students should focus on test 1 (compaction) as well as obtain their soil samples for tests 2 and 3, which they will complete inside.
10. After students have completed their soil tests, if it is determined that they should consider making adjustments to the soil quality during the planting of the vegetation barrier, they should update their action plan document.

Test #1: Soil compaction (to be completed outdoors)

1. Students will use the shovel to determine how compacted the soil is, based on observations during sample collection.
2. Compacted soil can be hard and solid. Students should observe how far they are able to push the soil probe into the ground to obtain a sample. The depth the shovel is able to reach will help determine the compaction of the soil as well as if there is a gravel or rock bed not far below the surface.
3. Have students complete the Test #1 section of their data sheet.
4. After the compaction test, students should divide the soil samples that they collected in the probe into two sealable plastic bags. Students will use these samples for the soil texture and organic matter tests.

Test #2: Soil texture (can be completed indoors or outdoors)

1. Remove one of your two soil samples from its zip-sealed bag.

2. Measure 1-2 tablespoons of soil and place it in your hand. Add a small amount of water from a pipette until the soil is putty-like in texture. This step should be done slowly so that you avoid adding too much water at a time and creating a soil slurry.
3. Using the non-sharp side of a plastic knife, scrape any additional soil putty from your hands into the main soil clump.
4. **Part 1: Try to form the soil into a ball (section A of soil texture data sheet).**
5. Complete section A in the soil texture section of the data sheet.
6. **Part 2: Soil ribbons (section B of soil texture data sheet)**
7. Squeeze the ball with your thumb and forefinger, pushing in an upward motion.
8. Allow the ribbon to break after it is pushed past your forefinger.
9. Complete section B, based on how the soil breaks apart.
10. **Part 3: Smooth or gritty (section C of soil texture data sheet)**
11. Place a dime- to quarter-sized sample of the soil you rolled into a ball into the center of your palm.
12. Add a small amount of water using your pipette and rub the water into the sample with your index finger.
13. Using section C of the data sheet, answer if the soil sample is gritty (like sugar) or smooth (like flour).
14. Use the last section of the soil texture section of the data sheet to determine your soil composition based on the ribbon size and the texture.
15. Utilize page 21 of the Vegetation Barrier Toolkit (Guide #5 - Get to Know Your Soil - Soil Texture Flow Chart) to assist with this test as well.

Test #3: Organic matter (can be completed indoors or outdoors)

1. Take your second soil sample bag.
2. Keeping the bag sealed, break apart the soil in this sample. If possible, lay the bag flat on a white piece of paper.
3. Compare the color of your soil sample to the color chart on the data sheet to estimate the amount of organic matter contained in this sample.

Soil Testing Data Sheet

1. Describe your testing location (bare soil, vegetation on top/lawn, gravel present, etc.)

Soil compaction (Test #1)			
How deep did the soil probe go?	Soil compaction	Sample location 1	Sample location 2
Less than 4 inches	Severe		
4 to 12 inches	Moderate		
More than 12 inches	Acceptable		

Soil texture (Test #2) (Use this video to help demonstrate each part of this test). Additionally, utilize the Vegetation Barrier Toolkit (Guide #5 - Get to Know Your Soil - Soil Texture Flow Chart) to assist with this test as well.	**Circle one**
Section A: Does the soil form into a ball?	Yes. Soil contains other materials than sand. No. Soil is mostly sand and is too gritty to make a ball shape.
Section B: Does the soil ribbon?	Yes. The soil forms flat clumps that may break apart but do not crumble. (Answer the question in the box below.) No. The soil crumbles apart and does not make anything that appears like a flat band. (This means the soil is loamy sand.)
	How large is the soil ribbon? < 2.5-5cm—clay loam >5cm—type of clay

Section C: Is the soil gritty? Or smooth?	Yes. The soil is smooth (like wet flour). No. The sample feels gritty (like wet sand or sugar).

<2.5 cm ribbon	2.5-5 cm ribbon	>5cm ribbon
Gritty? Sandy loam	Gritty? Sandy clay loam	Gritty? Sandy clay
Smooth? Silt loam	Smooth? Silty clay loam	Smooth? Silty clay
Neither gritty nor smooth? Loam	Neither gritty nor smooth? Clay loam	Neither gritty nor smooth? Clay

My soil composition: _____

Organic compounds in the soil (Test #3)

Soil color	Munsell soil value	Organic matter (%)
	<2	>10
	3	5-10
	4	3-4
	5	1-2
	>5	<1

Simplified soil color chart for estimating organic matter content of soils from Illinois. (Credit: Bryant Scharenbroch)

How much organic matter do you believe is in your soil? _____
Soil that we want to grow trees in is made of about 4% to 6% organic matter. There are many ways to measure soil organic matter. Darker-colored soils typically have more organic matter.

Do you believe your soil has enough organic matter? Should we consider adding mushroom compost or biosolids to the soil during a vegetation barrier planting to improve the organic matter/soil quality?

Choosing the Trees for Your Barrier – Final Planning Activity

Background and activity overview

In this activity, students will determine which trees will be best suited for their vegetation barrier based on the observations and data they have collected. Students will research different tree species and create fact sheets to include in a final proposal for the vegetation barrier installation.

Next Generation Science Standards

- **3-5-ETS1-2.** Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **MS-LS2-5.** Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- **MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **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.

Learning objectives

- Students will determine which tree species would be best suited for their vegetation barrier.
- Students will identify how different types of trees may provide different benefits to mitigate air pollution and improve air quality at their site.
- Students will evaluate species selection using set criteria.

Materials

- One tree species selection chart per student group
- Internet access for tree species research

Procedure

1. Have students retrieve their soil testing data sheet and site evaluation data sheet.
2. Students will use this data to help them determine which species may be best for their planting.
3. **Please note:** Information on soil drainage is included in the planting guide. It is recommended that this criteria be considered before species selection is finalized. Soil drainage is not one of the soil tests recommended for students to test; therefore be sure maintenance staff or other support staff members for this project consider this factor in the final plan for the vegetation barrier installation.
4. Using the tree species selection chart, students should refer to their data to help them determine some tree species to consider in the planting. (Also located in Field Sheet #6 - Choosing the Right Trees for Your Site)
5. Once students have determined which species may be the best fit, they will research different species to create fact sheets to include in their final planting proposal.

Tree Species Selection Chart

Part 1: Eliminate these species, based on your site conditions.
Answer the questions below. If you answer yes, you should cross off this species from preferred species charts.

Measurement question	AVOID
Is the planting site less than 15 feet from a roadway? Yes ____ No ____ If yes...	Road salt could affect the air and soil around the planting site, so avoid × Norway spruce
Is the site in full shade? Yes ____ No ____ If yes ...	There is not enough sunlight at this site, so avoid × All vegetation barrier tree species
Is the site in partial shade? Yes ____ No ____ If yes ...	There is a moderate amount of sunlight at this site, so avoid × Chinese juniper × Eastern red cedar

Part 2: Preferred species lists

1. Review your site evaluation data and determine if you think this tree would be a good fit for your site. If yes, put a check mark in the last column.
2. Consider both evergreen and deciduous species charts.

Preferred Evergreen Species

Species	Full-grown size	Growth rate	Best conditions	Notes	Good for your site?
Norway spruce *Picea abies*	H: 40-60 ft W: 25-30 ft	Moderate to fast	Light: Full sun to shade Drought: Moderately sensitive Waterlogging: Moderately sensitive	Avoid cultivars with weeping or dwarf shapes	
Black Hills spruce *Picea glauca* v. *densata*	H: 20-40 ft W: 10-15 ft	Slow to moderate	Light: Full sun to shade Drought: Moderately tolerant Waterlogging: Sensitive	Avoid cultivars with dwarf shapes	

Species	Full-grown size	Growth rate	Best conditions	Notes	Good for your site?
Chinese juniper *Juniperus chinensis*	H: 50-60 ft W: 15-20 ft	Slow	Light: Full sun Drought: Tolerant Waterlogging: Sensitive	Female cultivars*: • Fairview • Hetzii Columnaris • Keteleeri • Perfecta	
Eastern red cedar *Juniperus virginiana*	H: 40-50 ft W: 8-20 ft	Moderate	Light: Full sun Drought: Tolerant Waterlogging: Sensitive	Female cultivars*: • Emerald Sentinel • Canaertii	

Preferred Deciduous Species

Species	Full-grown Size	Growth rate	Best conditions	Notes	Good for your site?
Bald-cypress *Taxodium distichum*	H: 50-70 ft W: 20-30 ft	Moderate	Light: Full to partial sun Drought: Moderately sensitive Waterlogging: Tolerant	• Avoid cultivars with dwarf shapes • Shawnee Brave cultivar has a narrow form (15-20 ft wide)	
Red maple *Acer rubrum*	H: 40-60 ft W: 35-45 ft	Moderate	Light: Full to partial sun Drought: Moderately tolerant Waterlogging: Moderately tolerant	Female cultivars*: • Autumn Glory • Bowhall • Davey Red • Doric • Embers • Festival • October Glory • Red Skin • Red Sunset • Armstrong Gold: narrow (12 ft wide)	

Species	Full-grown Size	Growth rate	Best conditions	Notes	Good for your site?
Silver linden *Tilia tomentosa*	H: 50-70 ft W: 25-40 ft	Moderate	Light: Full to partial sun Drought: Moderately tolerant Waterlogging: Sensitive	• Avoid cultivars with dwarf shapes	
Nannyberry *Viburnum lentago*	H: 20-35 ft W: 10-20 ft	Moderate	Light: Full to partial sun Drought: Moderately tolerant Waterlogging: Moderately tolerant		
Allegheny serviceberry *Amelanchier laevis*	H: 20-25 ft W: 15-25 ft	Moderate	Light: Partial sun Drought: Moderately tolerant Waterlogging: Moderately tolerant		
Downy serviceberry *Amelanchier arborea*	H: 15-25 ft W: 15-25 ft	Moderate	Light: Full to partial sun Drought: Moderately tolerant Waterlogging: Moderately tolerant		
Chokecherry *Prunus virginiana*	H: 20-35 ft W: 18-25 ft	Moderate	Light: Full to partial sun Drought: Tolerant Waterlogging: Moderately tolerant		

* A cultivar is a variety of a species that has been bred for specific traits. If your vegetation barrier will be near a location where people spend time outside, we strongly recommend choosing a female cultivar of Chinese juniper or eastern red cedar because these trees will not produce any pollen. All spruce trees produce pollen because they do not have separate male and female trees, although spruce pollen is less allergenic compared to pollen from other tree species.

Research and select your trees

1. For each check-marked tree above, complete additional research to help you choose the trees you would like included in your barrier.
2. Create a fact sheet for each tree species to include in your final proposal for the Vegetation Barrier Project. This fact sheet could include images of the tree species, growth information (size), and tree feature details (fall color, leaf shape, bark texture, etc.).

Bringing it All Together – Planting Design Proposal

Background and activity overview

In this activity, students will create a formal proposal for the installation of a vegetation barrier at their school site. Students will utilize the RAFT strategy to develop their proposal with a specific audience, topic, and format in mind. They will need to create a presentation that demonstrates why this is needed in their school community and why improving air quality is so important.

Background and activity overview

RAFT stands for role, audience, format, and topic. It is a writing strategy that helps students understand their role as a writer and how to effectively communicate their ideas and mission clearly so that the reader can easily understand everything written. It helps students focus on the audience they will address, the varied formats for writing, and the topic. This strategy encourages students to explore their own voices and formats for presenting their ideas about the content they are learning.

Role of the writer: Who are you as the writer?
Audience: To whom are you writing?
Format: In what format are you presenting this information?
Topic: What are you writing about?

The format can be flexible. Students can choose from a menu of formats to communicate the content. Additionally, this strategy can be differentiated by changing the role or audience to make it more challenging or to have students explain content within a variety of contexts. See below for more RAFT ideas.

More information about the RAFT strategy can be found through the National Council for Teachers of English (NCTE) at readwritethink.org or by reading *Strategic Writing: The Writing Process and Beyond in the Secondary English Classroom* by Deborah Dean (2006).

Next Generation Science Standards

- **3-5-ETS1-2**. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- **MS-LS2-5**. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.
- **MS-ESS3-3.** Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
- **MS-ETS1-1.** Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- **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.

Learning objective

- Students will develop a proposal presentation to convince a group of stakeholders that they should install a vegetation barrier on their school site.

Materials

- RAFT graphic organizer (1 per student)
- Writing utensil(s)
- Previous work on the vegetation barrier site investigations (Soil Testing Data Sheet, Tree Species Selection Chart, Site Evaluation Data Sheet, Science Notebook Activity)
- Internet access or printed copies of the U.S EPA School Best Practice Guide

Procedure

1. Explain to students that they are going to take the information they have gathered about vegetation barriers, air pollution, and the air quality at their site, and develop a plan to convince the other school and community stakeholders that a vegetation barrier should be installed. If a vegetation barrier is not the best solution for a site, consider other air quality mitigation measures to improve air quality at your site. For additional information, review the U.S EPA School Best Practice Guide.
2. Students should consider the role, audience, format, and topic when creating their persuasive presentation. They can utilize the graphic organizer below to develop their presentation.
3. After students have created their presentation, consider hosting a panel discussion or create a platform for students to share their ideas and get feedback from the other community stakeholders.
4. Invite administrative staff members, parents, and community leaders to be a part of the student presentations.
5. Optional: Have students consider making a draft budget as a subsequent step, based on the age of your students and if you think this will be an important part of their presentation. Their budget could include estimated costs or project expenses.

RAFT Graphic Organizer - Vegetation Barrier Proposal Presentation

Goal: To persuade the decision makers in your school and community to build a vegetation barrier on your school campus to improve air quality.

Begin by choosing a format for your presentation.

Role	Audience	Format	Topic
Student who recently learned about the air quality at your school site.	School administrators, decision makers, and community members	• Powerpoint presentation • Video • Website • Jamboard • Poster	Air quality in your school and what you think should be done to improve it.

Next use the organizer below to help you organize the content of your presentation.

Audience: • Who are you going to be presenting to? • What do you know about this audience? • What types of information do they like to receive (data, emotional response, potential project impact, etc.)	
Topic: • What information should you consider including in your presentation? • What have you learned thus far that may be helpful to include? • How do you think you should use this information to tell a story? • Is there other information you should gather that would make your presentation more persuasive?	
Format: • Which type of presentation do you think will best tell your	

story/share your information? ● What types of visuals do you think you should include to demonstrate your points?	

Vegetation Barrier Lesson Plan Appendix

Additional linked resources

- "What Is in the Outdoor Air? Exploring Particulate Matter (PM) Sources and Air Quality Outdoors" (U.S. EPA's Outdoor Air Lesson). - Utilized in **Observation - Understanding and Measuring Air Quality at Your Site** (pages 10-17 of this document) - Printed copy in the toolkit binder.
- AirBeam2 Quickstart Guide (from U.S. EPA) (U.S. EPA's quickstart guide to using the AirBeam2 Sensor- Utilized in **Observation - Understanding and Measuring Air Quality at Your Site** (pages 10-17 of this document) - Printed copy in the toolkit binder.
- Sample Walking Map (linked slide show) (The Morton Arboretum sample walking route to measure air quality onsite)- Utilized in **Observation - Understanding and Measuring Air Quality at Your Site** (pages 10-17 of this document)-
- "Power of Plants" Lesson Plan, Activity Pages, and Teacher's Answer Key- (U.S. EPA's Power of Plants Lesson Plan) - Utilized in **Planning Your Vegetation Barrier** (pages 29-31 of this document) - Printed copy in the toolkit binder.

Please note: *This toolkit contains the AirBeam2 Sensor, and there are some considerations to understand with use of this sensor. Current particulate matter (PM) air sensors (sensors) most effectively detect particles within the size range of about 0.5 - 2.5 microns (um) in diameter. However, research has shown (for example, Lin et al., 2016[2]) that vegetation is most effective at removing very small particles (called ultrafine particles, smaller than 0.1um) and larger particles (called coarse particles, larger than 2.5um), which fall outside of this optimal measurement range. Therefore, when using a PM sensor like the AirBeam2, we must realize that this sensor is not seeing the differences in the very small and larger particle concentrations, so we may likely not see the significant reductions in PM after the installation and maturation of a vegetative barrier using the AirBeam2 or other lower cost sensors. Additionally, it is important to note that vegetation barriers may take a few years to establish and demonstrate significant changes to air quality measurements. School sites should consider including and adopting additional mitigation strategies (outlined in the "Action Planning Worksheet - Air Quality and Vegetation Barrier" activity).*

Additional resources and links

- **The Morton Arboretum Plant Clinic -** The Morton Arboretum Plant Clinic is a leading source of science-based advice about trees, plants, and landscapes, helping gardeners and landscape professionals throughout the Chicago region and the world have healthy, attractive, well-chosen plants. Trained staff and volunteers are available by phone or by email to help with tree and plant selection, identifying and coping with pests and diseases, and other concerns.
- **The Morton Arboretum education resources**
    - **Virtual Curriculum Bundles (free):** These bundles are divided by grade level, and all activities are aligned to Next Generation Science Standards (NGSS) and Common Core State Standards in some cases as well, often including cross-curricular lessons and activities. These Virtual Bundles align to life science themes and come in three parts: introductory activities (to introduce the topic and domain-specific vocabulary), pre-recorded teaching videos, and concluding activities (to assess student learning). These bundles include teacher answer keys and standards-aligned rubrics (when necessary).
    - **Field trip programs (fee-based with potential grant opportunities):** Spark curiosity about science, nature, and art with one of the many programs available to school groups and classrooms at The Morton Arboretum.

[2] Lin, M.Y., Hagler, G., Baldauf, R., Isakov, V., Lin, H.Y. and Khlystov, A., 2016. The effects of vegetation barriers on near-road ultrafine particle number and carbon monoxide concentrations. *Science of the Total Environment*, 553, pp.372-379, https://doi.org/10.1016/j.scitotenv.2016.02.035.

    - **Classroom items for loan:** The Morton Arboretum has developed free loan resources for teachers to check out and implement in their classroom instruction. Each Discovery Bin contains materials, tools, and lessons to bring the Next Generation Science Standards (NGSS) alive in your classroom. Bins are organized by grade level and are aligned with our current field trip offerings. Check out a bin before or after your trip to extend your students' learning. These bins are available on a loaning basis and can be borrowed for up to two weeks at a time.
    - **Guest speaker/outreach:** Schools planning a vegetation buffer for their site can also coordinate with The Morton Arboretum Education and Science Conservation departments to provide students, staff, and community members with a presentation on urban soils, urban trees, or other related topics for their buffer. These outreach events can take place virtually or in person and would be subject to staff availability during the planning process. For details, contact The Morton Arboretum's Education Department.
- Extension Master Gardener Programs (USDA): Find your local Extension Master Gardener program from each of the 50 states for more support. These trained professionals and volunteers recommend university and research-based information through the Cooperative Extension System.
- **United States Environmental Protection Agency (U.S. EPA)**
    - **Air Quality Sensor Loaning Program:** Region 5 of the U.S. Environmental Protection Agency (U.S. EPA) has developed a series of lessons and loaning resources for libraries and education institutions in order to provide community members and youth with access to air quality monitoring tools and sensors.
    - **Measuring Air Quality Improvements from Vegetative Barriers:** This is a set of lesson plans designed to complement U.S. EPA's Air Quality Sensor Loaning Program. Lesson plans include classroom and field activities that utilize mobile air quality sensors.
    - **Environmental Resources for Educators:** U.S. EPA has curated a collection of lesson plans and classroom activities on a wide range of environmental topics, including air pollution.
    - **EPA's Best Practices for Reducing Near-Road Pollution at Schools:** This publication can help school communities identify strategies for reducing traffic-related pollution exposure at schools located downwind from heavily traveled roadways (such as highways), along corridors with significant trucking traffic, or near other traffic or vehicular pollution sources. Many of these strategies are already being used by schools across the country to reduce exposures to traffic-related air pollution.
    - Idle-Free Schools Toolkit for a Healthy School Environment: The Idle-Free Schools Toolkit includes information needed to run an effective idling reduction campaign at a school to reduce student exposure to toxic vehicle exhaust. The toolkit also provides the resources to make this a student-run science or community-involvement project, providing students with the opportunity to learn how to run a public service campaign while expanding their science and math skills.
    - Air Quality Flag Program. As part of this program, each day the school/organization raises a flag that corresponds to how clean or polluted the air is. The color of the flag matches the U.S. EPA's Air Quality Index (AQI): green, yellow, orange, red, and purple. On unhealthy days, the school/organization can use this information to adjust physical activities to help reduce exposure to air pollution, while still keeping people active.