MODULE 3

Air Pollution in the Community

Combustion, Particulate Matter, and Community Health

Module Overview

Burning fuel, the chemical process of combustion, has been a part of human civilization since we first started using fire for warmth and cooking. When the Industrial Revolution provided us electricity through widespread use of coal-burning power plants, combustion brought all new benefits, and many serious drawbacks. The advent of cars and trucks driven by internal combustion engines multiplied these effects. Combustion produces particulate matter, a form of air pollution that can have very serious repercussions for human health and the environment. In this module, students will take on the role of concerned community members who fear that their proximity to sources of particulate matter, both from combustion and other processes, is endangering their health. Acting as citizen scientists, they will learn about where particulate matter comes from, and how it affects human health. They will also measure particulate matter in their community. The module culminates in a simulated public meeting before a state committee where students will take on different roles to argue whether or not diesel trucks should be banned from traveling through residential neighborhoods.

Anchor phenomenon: Streams of particulate matter emitted from diesel vehicles.

Pacing

- 9 activities (2 optional) + summative assessment
- Approximately 10 class periods (plus 2 optional)

Module Contents

When to Teach This Module

Finding the right place within a science scope and sequence to investigate air pollution with students can be tricky. Below you will find some information about the module that can help you decide where this it might fit into your own plans for student leaning:

- **Connection to Ecosystems**: Air pollution can have a tremendous effect on the health of ecoystems. The NGSS standards focus on how changes to a physical or biological component of an ecosystem can affect populations. In this module, the change in the ecoystem is particulate matter pollution, and the population affected is humans. Alignment to the standard would require additional examples of how other populations in the ecosystem is affected, but this module would fit well within a larger investigation of pollutants affecting ecosystems.

- **Connection to Human Health:** Air pollution from particulate matter pollution can have a significant impact human health. This module focuses specifically on how the health of a community is affected by particulate matter pollution. As such, it would fit well within a unit on the human respiratory and circulatory systems to add a real-world example of how the environment affects the health of human body systems.

- **Connection to Natural Resource Usage:** Air pollution is very much a story about human population and the consequences of how we use natural resources. While the module itself does not go into detail about kinds of natural resources, it would fit well as a part of a larger investigation of fossil fuels, and how our usage of those fuels affects human health.

Standards Overview

Middle School NGSS standards alignment

Performance Expectations

Focus PE:

MS-ESS3-3. Apply scientific principles to design a method for monitoring ~~and minimizing~~ a human impact on the environment.* [Clarification Statement: Examples of the design process include examining human environmental impacts, assessing the kinds of solutions that are feasible, and designing and evaluating solutions that could reduce that impact. Examples of human impacts can include water usage (such as the withdrawal of water from streams and aquifers or the construction of dams and levees), land usage (such as urban development, agriculture, or the removal of wetlands), and pollution (such as of the air, water, or land).]

Background PEs:

MS-LS2-4. Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. [Clarification Statement: Emphasis is on recognizing patterns in data and making warranted inferences about changes in populations, ~~and on evaluating empirical evidence supporting arguments about changes to ecosystems~~.]

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

Science & Engineering Practices

Focus SEP: Engaging in Argument from Evidence
Engaging in argument from evidence in 6–8 builds on K–5 experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s).

- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Background SEP: Analyzing Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.

- Use graphical displays (e.g., maps, charts, graphs, and/or tables) of large data sets to identify temporal and spatial relationships.
- Distinguish between causal and correlational relationships in data.

Background SEP: Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

- Apply scientific ideas, principles, and/or evidence to construct, revise and/or use an explanation for real-world phenomena, examples, or events.
- Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re-testing.

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems
Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. (MS-ESS3-3)

Background DCI: LS2.A: Interdependent Relationships in Ecosystems
Organisms, and populations of organisms, are dependent on their environmental interactions ~~both with other living things and~~ with nonliving factors. Growth of organisms and population increases are limited by access to resources.

Background DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. (MS-LS2-4)

Background DCI: ETS1.B: Developing Possible Solutions
A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. Models of all kinds are important for testing solutions.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Prediction – Events have causes, sometimes simple, sometimes multifaceted. Deciphering causal relationships, and the mechanisms by which they are mediated, is a major activity of science and engineering.

- Relationships can be classified as causal or correlational, and correlation does not necessarily imply causation.
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- Phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability

NGSS 5th Grade Standards alignment

Performance Expectations:

Focus SEP: 5-ESS3-1. Obtain and combine information about ways individual communities use science ideas to protect the Earth's resources and environment.

Background SEP: 5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact. [Clarification Statement: Examples could include the influence of the ocean on ecosystems, landform shape, and climate; the influence of the atmosphere on landforms and ecosystems through weather and climate; and the influence of mountain ranges on winds and clouds in the atmosphere. The geosphere, hydrosphere, atmosphere, and biosphere are each a system.] [Assessment Boundary: Assessment is limited to the interactions of two systems at a time.]

Science & Engineering Practices

Focus SEP: Engaging in argument from evidence
Engaging in argument from evidence in 3–5 builds on K–2 experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s).

- Construct and/or support an argument with evidence, data, and/or a model.
- Use data to evaluate claims about cause and effect.

Background SEP: Analyzing and interpreting data
Analyzing data in 3–5 builds on K–2 experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations.
When possible and feasible, digital tools should be used.

- Represent data in tables and/or various graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships.
- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.

Background SEP: Constructing explanations (for science) and designing solutions (for engineering)
Constructing explanations and designing solutions in 3–5 builds on K–2 experiences and progresses to the use of evidence in constructing explanations that specify variables that describe and predict phenomena and in designing multiple solutions to design problems.

- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.

Disciplinary Core Ideas

Focus DCI: ESS3.C: Human Impacts on Earth Systems
Human activities in agriculture, industry, and everyday life have had major effects on the land, vegetation, streams, ocean, air, and even outer space. But individuals and communities are doing things to help protect Earth's resources and environments. (5-ESS3-1)

Background DCI: ETS1.B: Developing Possible Solutions
Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved.

Crosscutting Concepts

Focus CCC: Cause and Effect: Mechanism and Explanation
Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain new contexts.

- Events that occur together with regularity might or might not be a cause and effect relationship.

Virginia Standards of Learning (SOLs) alignment

Science & Engineering Practices	
5.1 (c)	Interpreting, analyzing, and evaluating data. The student will… • represent and analyze data using tables and graphs • organize simple data sets to reveal patterns that suggest relationships • use data to evaluate and refine design solutions
5.1 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct and/or support arguments with evidence, data, and/or a model • generate and compare multiple solutions to problems based on how well they meet the criteria and constraints
6.1 (c)	Interpreting, analyzing, and evaluating data. The student will… • organize data sets to reveal patterns that suggest relationships • construct, analyze, and interpret graphical displays of data • use data to evaluate and refine design solutions
6.1 (d)	Constructing and critiquing conclusions and explanations. The student will… • construct scientific explanations based on valid and reliable evidence obtained from sources (including the students' own investigations) • generate and compare multiple solutions to problems based on how well they meet the criteria and constraints
Content Standards	
6th Grade 6.9	The student will investigate and understand that humans impact the environment and individuals can influence public policy decisions related to energy and the environment. Key ideas include: c) major health and safety issues are associated with air and water quality; e) preventive measures can protect land-use and reduce environmental hazards; and f) there are cost/benefit tradeoffs in conservation policies.
Earth Science ES.11	The student will investigate and understand that the atmosphere is a complex, dynamic system and is subject to long-and short-term variations. Key ideas include c) natural events and human actions may stress atmospheric regulation mechanisms; and d) human actions, including economic and policy decisions, affect the atmosphere.

Common Core State Standards alignment

Literacy Standards	
RST.6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
RST.6-8.4	Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6-8 texts and topics.
WHST.6-8.1	Write arguments focused on discipline-specific content.
WHST.6-8.1B	Support claim(s) with logical reasoning and relevant, accurate data and evidence that demonstrate an understanding of the topic or text, using credible sources.
SL.8.1	Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.
SL.8.4	Present claims and findings, emphasizing salient points in a focused, coherent manner with relevant evidence, sound valid reasoning, and well-chosen details; use appropriate eye contact, adequate volume, and clear pronunciation.
Math Standards	
6.SP.B.5	Summarize numerical data sets in relation to their context

5E Module Flow

Activity 1 (Engage): The Trouble With Trucks
Timing: 45 minutes
Purpose: Introducing the anchor phenomenon
- ✓ Students will ask questions to clarify and define the phenomenon of point-source air pollution (truck exhaust)

Activity 2 (Explore): What Happens When Things Burn?
Timing: 2 class periods (90-120 minutes)
Purpose: Connecting the physical phenomenon of exhaust from trucks with the scientific concepts of combustion and particulate matter
- ✓ Students will know that particulate matter (PM) comes from combustion
- ✓ Students will have an intuitive and a cognitive understanding of what PM 10 and PM 2.5 are.

Activity 3a (Explore): Measuring Particulate Matter Using Technology
Timing: 2-3 class periods (90-120 minutes)
Purpose: Measuring particulate matter in and around the school to learn how to measure PM and to determine if there are any air quality issues in the local school community
- ✓ Students will be able to measure particulate matter using technology
- ✓ Students will be able to use their measurements to draw and support conclusions about how healthy the air is near the school

Activity 3b (Explore): Measuring Particulate Matter Using Engineering
Timing: 3-4 class periods
Purpose: Building particulate matter collectors to use around the school to develop engineering skills, learn how to measure PM, and to determine if there are any air quaity issues in the school community
- ✓ Students will be able to design, test, and deploy particulate matter collectors
- ✓ Students will be able to collect and analyze data to determine what areas of the school community have high levels of particulate matter in the air

Activity 4 (Explain): Particulate Matter and Human Health
Timing: 30-45 minutes
Purpose: Understanding how particulate matter affects human health at a physiological level
- Students will be able to identify the major health risks of particulate matter pollution
- Students will be able to compare and contrast the health effects of PM 2.5 and PM 10

Activity 5 (Elaborate): Particulate Matter in the Community
Timing: 45-60 minutes
Purpose: Understanding how particulate matter affects human health at the community level

- ✓ Students will analyze data in order to connect particulate matter pollution to health outcomes in a community
- ✓ Students will be able to distinguish between causation and correlation

Activity 6 (Elaborate): Air Toxics in the Community (optional)
Timing: 45 minutes
Purpose: Understanding hazardous air pollution and how it can affect communities

- Students will learn how scientists identify sources of toxic chemicals in the community
- Students will understand the difference between the criteria pollutants and toxic chemical pollutants

Activity 7 (Elaborate): Who is Polluting in My Neighborhood (optional)
Timing: 45-60 minutes
Purpose: Identifying potential sources of harmful air pollution in local neighborhoods

- Students will research air pollution sources in their communities and analyze their findings

Activity 8 (Elaborate): Not in My Backyard: Environmental Justice
Timing: 60 minutes
Purpose: Investigating environmental (in)justice using EPA's EJ Screen tool

- Students will understand the concept of environmental justice
- Students will investigate environmental justice in their community to see if certain groups of people are more frequently affected by air pollution

Activity 9 (Evaluate): Public Hearing on Banning Diesel Trucks in the Neighborhood
Timing: 2-3 class periods (120-180 minutes)
Purpose: Understanding the public policy of air quality, and learning to advocate for air quality issues

- Students will explore and learn different perspectives on public policy related to air quality
- Students will make arguments based on evidence about whether or not diesel trucks should be banned in the community

Module Materials

Activity 1 (Engage): The Trouble With Trucks

- ❒ Handouts: none
- ❒ Materials needed: Computer & projector, sticky notes, sentence strips
- ❒ Optional materials: Air Quality Champions interview (see end of module)

Activity 2 (Explore): What Happens When Things Burn?

- ❒ Handouts: What Happens when Things Burn? notes sheet
- ❒ Materials needed: Two candles (large and small) and lighter/matches, glass jar that you can put over the small candle (or a metal can with the label removed), flour, flashlight, orange/match
- ❒ Optional materials: aluminum foil, ice, paper

Activity 3a (Explore): Measuring Particulate Matter Using Technology

- ❒ Handouts: Measuring PM in the Classroom, Measuring PM in the School Community
- ❒ Materials needed: AirBeams (approx. 1:4 students; see module for details), Android device with AirCasting app, clipboards, computer & projector
- ❒ Optional materials: Student computers

Activity 3b (Explore): Measuring Particulate Matter Using Engineering

- ❒ Handouts: Design a Partculate Matter Detector
- ❒ Materials needed: Graph paper, magnifying glass/dissecting scope, materials for building and testing the PM detectors (see module for details), scissors, additional blank paper
- ❒ Optional materials: none

Activity 4 (Explain): Particulate Matter and Human Health

- ❒ Handouts: The Health Effects of Particulate Matter
- ❒ Materials needed: Sentence strips, computer & projector
- ❒ Optional materials: Student computers

Activity 5 (Elaborate): Particulate Matter in the Community

- ❒ Handouts: Citizen Science: How Particulate Matter Pollution Affects a Community
- ❒ Materials needed: Graph paper
- ❒ Optional materials: Student computers

Activity 6 (Elaborate): Air Toxics in the Community (optional)

- ❒ Handouts: Air Toxics in the Community, Air Toxics and Criteria Pollutants
- ❒ Materials needed: Computer & projector, speakers
- ❒ Optional materials: none

Activity 7 (Elaborate): Who is Polluting in My Neighborhood? (optional)

- ❒ Handouts: Air Pollution Sources in My Community
- ❒ Materials needed: Computer & projector
- ❒ Optional materials: Student computers (highly recommended)

Activity 8 (Elaborate): Not In My Backyard: Environmental Justice

- ❒ Handouts: Environmental Justice Investigation Guide
- ❒ Materials needed: Computer & projector, internet connection
- ❒ Optional materials: Student computers (highly recommended)

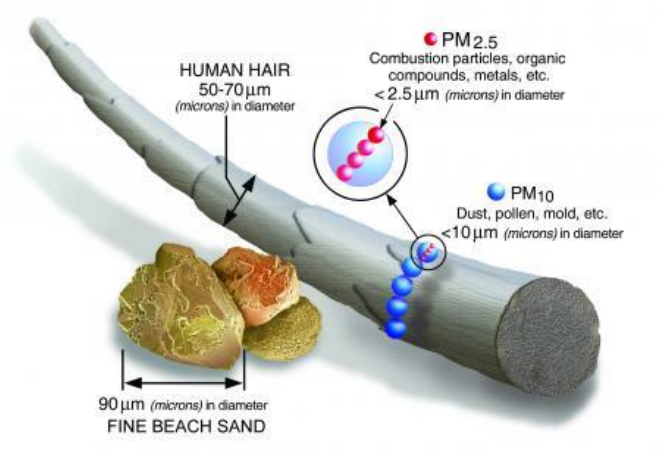
Activity 9 (Evaluate): Public Hearing on Banning Diesel Trucks in the Neighborhood

- ❒ Handouts: Role play stakeholder cards, Diesel truck ban role play scenario, Role play planning, hearing notes sheet, Cast Your Vote writing prompt
- ❒ Materials needed: Research materials (see module for details), presentation rubric (provided)
- ❒ Optional materials: Student computers, news article on California's diesel truck manufacturing phase-out

Teacher Background Information

Particulate Matter (PM) Basics

PM stands for particulate matter (also called particle pollution): the term for a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Others are so small they can only be detected using an electron microscope.



Particle pollution includes:

- **PM_{10}** : inhalable particles, with diameters that are generally 10 micrometers and smaller; and
- **$PM_{2.5}$** : fine inhalable particles, with diameters that are generally 2.5 micrometers and smaller.
    - How small is 2.5 micrometers? Think about a single hair from your head. The average human hair is about 70 micrometers in diameter – making it 30 times larger than the largest fine particle.

These particles come in many sizes and shapes and can be made up of hundreds of different chemicals. Some are emitted directly from a source, such as construction sites, unpaved roads, fields, smokestacks or fires. Most particles form in the atmosphere as a result of complex reactions of chemicals such as sulfur dioxide and nitrogen oxides, which are pollutants emitted from power plants, industries and automobiles.

What are the Harmful Effects of PM?
Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs and some may even get into your bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or $PM_{2.5}$, pose the greatest risk to health.

Fine particles are also the main cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas.

What is Being Done to Reduce Particle Pollution?
EPA regulates inhalable particles. Particles of sand and large dust, which are larger than 10 micrometers, are not regulated by EPA. EPA's national and regional rules to reduce emissions of pollutants that form PM will help state and local governments meet the Agency's national air quality standards.

How Can I Reduce My Exposure to PM?
You can use air quality alerts to protect yourself and others when PM reaches harmful levels:

AirNow: Every day the Air Quality Index (AQI) tells you how clean or polluted your outdoor air is, along with associated health effects that may be of concern. The AQI translates air quality data into numbers and colors that help people understand when to take action to protect their health.

- Go to About AirNow to learn how you can get AQI notifications.
- Also learn how the Air Quality Flag Program can help air agencies, schools, and other community organizations to notify their citizens of harmful conditions and adjust outdoor physical activities as needed.

Source: Particulate Matter (PM) Pollution, US EPA. https://www.epa.gov/pm-pollution/particulate-matter-pm-basics

Principles of Environmental Justice

Delegates to the First National People of Color Environmental Leadership Summit held on October 24-27, 1991, in Washington DC, drafted and adopted 17 principles of Environmental Justice. Since then, *The Principles* have served as a defining document for the growing grassroots movement for environmental justice.

WE, THE PEOPLE OF COLOR, gathered together at this multinational People of Color Environmental Leadership Summit, to begin to build a national and international movement of all peoples of color to fight the destruction and taking of our lands and communities, do hereby re-establish our spiritual interdependence to the sacredness of our Mother Earth; to respect and celebrate each of our cultures, languages and beliefs about the natural world and our roles in healing ourselves; to ensure environmental justice; to promote economic alternatives which would contribute to the development of environmentally safe livelihoods; and, to secure our political, economic and cultural liberation that has been denied for over 500 years of colonization and oppression, resulting in the poisoning of our communities and land and the genocide of our peoples, do affirm and adopt these Principles of Environmental Justice:

1) **Environmental Justice** affirms the sacredness of Mother Earth, ecological unity and the interdependence of all species, and the right to be free from ecological destruction.

2) **Environmental Justice** demands that public policy be based on mutual respect and justice for all peoples, free from any form of discrimination or bias.

3) **Environmental Justice** mandates the right to ethical, balanced and responsible uses of land and renewable resources in the interest of a sustainable planet for humans and other living things.

4) **Environmental Justice** calls for universal protection from nuclear testing, extraction, production and disposal of toxic/hazardous wastes and poisons and nuclear testing that threaten the fundamental right to clean air, land, water, and food.

5) **Environmental Justice** affirms the fundamental right to political, economic, cultural and environmental self-determination of all peoples.

6) **Environmental Justice** demands the cessation of the production of all toxins, hazardous wastes, and radioactive materials, and that all past and current producers be held strictly accountable to the people for detoxification and the containment at the point of production.

7) **Environmental Justice** demands the right to participate as equal partners at every level of decision-making, including needs assessment, planning, implementation, enforcement and evaluation.

8) **Environmental Justice** affirms the right of all workers to a safe and healthy work environment without being forced to choose between an unsafe livelihood and unemployment. It also affirms the right of those who work at home to be free from environmental hazards.

9) **Environmental Justice** protects the right of victims of environmental injustice to receive full compensation and reparations for damages as well as quality health care.

10) **Environmental Justice** considers governmental acts of environmental injustice a violation of international law, the Universal Declaration On Human Rights, and the United Nations Convention on Genocide.

11) **Environmental Justice** must recognize a special legal and natural relationship of Native Peoples to the U.S. government through treaties, agreements, compacts, and covenants affirming sovereignty and self-determination.

12) **Environmental Justice** affirms the need for urban and rural ecological policies to clean up and rebuild our cities and rural areas in balance with nature, honoring the cultural integrity of all our communities, and provided fair access for all to the full range of resources.

13) **Environmental Justice** calls for the strict enforcement of principles of informed consent, and a halt to the testing of experimental reproductive and medical procedures and vaccinations on people of color.

14) **Environmental Justice** opposes the destructive operations of multi-national corporations.

15) **Environmental Justice** opposes military occupation, repression and exploitation of lands, peoples and cultures, and other life forms.

16) **Environmental Justice** calls for the education of present and future generations which emphasizes social and environmental issues, based on our experience and an appreciation of our diverse cultural perspectives.

17) **Environmental Justice** requires that we, as individuals, make personal and consumer choices to consume as little of Mother Earth's resources and to produce as little waste as possible; and make the conscious decision to challenge and reprioritize our lifestyles to ensure the health of the natural world for present and future generations.

A pdf version of these principles can be found here: https://www.ejnet.org/ej/principles.pdf

Additional Information about Environmental Justice

- EPA Tools to Support Environmental Justice: https://www.epa.gov/healthresearch/tools-support-environmental-justice
- EPA: How to Interpret a Standard Report in EJ Screen: https://www.epa.gov/ejscreen/how-interpret-standard-report-ejscreen

Activity 1 (Engage): The Trouble With Trucks

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- Students will ask questions to clarify and define the phenomenon of point-source air pollution (truck exhaust)

Materials

- Computer & projector
- Sticky notes
- Sentence strips (or other paper)

Handouts

- ✓ I See, I Think, I Wonder
- ✓ Air Quality Champion interview (optional) – see end of module

Teacher Tip

- ✓ If there are other vehicles that your students see regularly (ex. buses), find pictures to show them of these vehicles as well as long as they clearly show the exhaust.

Activity summary: In this investigation kickoff activity, students are introduced to the phenomenon of truck exhaust and – in the extreme case – coal rolling. They take a moment to consider what they already know about truck exhaust and come up with some questions about the topic before they begin exploring in the next activity.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems

Warmup: What kinds of trucks have you seen in your neighborhood?

- Students may identify garbage trucks, delivery trucks (ex. Amazon), dump trucks (if they are near a construction site), tractor trailers (ex. at grocery stores), tanker trucks (at gas stations)
- The purpose of this warmup is to provide information about what kinds of trucks students are familiar with, which will help with the rest of the investigation.

1. **Frame the activity:** Tell students that today they are beginning a new investigation. For this investigation, they are going to take on the role of citizens who are concerned about something they have seen in their community. In just a moment, they will see the same thing. Will they have the same concerns as the citizens? Let's find out.

2. **Introduce the Phenomenon: Diesel trucks:** Hand out the I See, I Think, I Wonder sheet for students. Tell them that in a moment you are going to show one or more videos of this event. Their job is to write down what they see in the top row of the sheets using as many details as possible.

   Show students one or more of the videos or pictures below that show diesel vehicles emitting large amounts of pollution. Choose the video(s) that you think students will recognize from their own experience:

   - Garbage truck (video, show just the first minute) https://www.youtube.com/watch?v=TMzfOLfE0eA
   - Dump truck (video 1) https://www.youtube.com/watch?v=_VxpFDeBfIo (video 2): https://www.youtube.com/watch?v=sqyZ1N9hvNU
   - School bus (picture): http://electricschoolbuscampaign.org/wp-content/uploads/2018/04/Snapshot-5-4-7-2018-2-03-AM.png
   - "Rolling Coal" trucks modified to emit more pollution (video, show first 10 seconds) https://www.youtube.com/watch?v=kPljxIqcdUQ

You may also choose to show them a picture of a truck like this one if it is a kind of truck you think they will be familiar with:

Afterwards, have students turn to a partner and share what they saw. Encourage them to add their partners' observations to their sheets. Then have partners share with the whole group. Use questioning techniques to help students focus on the exhaust from these vehicles, and to be as descriptive of it as possible. Ask students if they have ever seen trucks like this before, either in their community or somewhere else.

3. **I think:** In the "I Think" section of their sheets, have students write what they know about exhaust. They will have different amounts of background knowledge, but they at least know that it is smoke that comes from trucks. Then have them turn to a partner to share what they know. Afterwards, have students share something that their partner said about exhaust.

4. **I wonder:** On their own, have students write down what they wonder about truck exhaust in question form (ex. Where does the exhaust come from?). While they are writing, pass out sticky notes to small groups of students. When they are done writing, have each small group write down whatever questions they have about truck exhaust – one question on each sticky note. When they are ready, go around the class and have each group share one of their questions. You can rewrite these questions on the board or have students bring their sticky notes up to the front. After each question, ask if any other groups have the same question, and make a note of how many groups have that question. Tell students to put a check mark on their stickies whenever a question they have has been shared so that they only share new questions. Continue around the room until all groups have shared their questions.

TEACHER NOTES

Vocabulary

- ✓ Make sure that students are familiar with what you are referring to when you use the word "exhaust." They don't need to know what it is yet, but they should know you are referring to the smoke coming from the trucks.

Differentiation

- If students have difficulty creating questions, you can provide them with types of scientific questions to kickstart their thinking. For example: what is this made of? Where did this come from? Is this dangerous to humans? Is this bad for the environment? Is there an alternative to this?

TEACHER NOTES

Recommended reading

- ✓ For more background information on how delivery trucks affect pollution in cities, check out this short article from Scientific American: https://www.scientificamerican.com/article/delivery-vehicles-increasingly-choke-cities-with-pollution/

Recommended

- At some point during the module, have students read the interview with this module's Air Quality Champion to get them into the frame of mind of the kind of work they'll be doing during this investigation.

5. **Summarize questions.** With students' help, organize the questions into 2-4 groups of similar questions, and choose 2-4 overarching questions to summarize the category (the class may need to create questions that summarize each category). Ideally these will be questions that align closely with the goals of the module (ex. what is truck exhaust made of? Is truck exhaust harmful). Write these big questions on sentence strips (or other paper) and put them up on the wall. Tell students that you will use the questions to help guide their investigation.

6. **Trucks in the community:** Now that students have seen the phenomenon, return to idea that citizens in the community are concerned about these trucks. Ask students why people might be concerned (ex. there are young children around, there are people with asthma, etc.) In particular, ask if there are there people in the community that might be more concerned than others? Have the students ever experienced one of these trucks driving by? What was it like? Use this as an opportunity to help students' make a personal connection to the phenomenon and see it as something to be concerned about.

7. **Formative assessment.** You may use students' I See, I Think, I Wonder sheets as a formative assessment, since this activity is designed to kickoff the investigation. Alternatively, have students write a short answer about their experience with trucks like the ones in the pictures: ex. How do they feel about these trucks?

Air Quality Champion

Joshua Shodeinde is an air quality champion in our community. As an engineer at the Maryland Department of the Environment, Joshua helps develop clean air regulations. Learn more about Joseph, his work, and how he protects air quality at the end of the module.

Name _____

STUDENT HANDOUT

I See, I Think, I Wonder

I See...
I Think...
I Wonder...

Activity 2 (Explore): What Happens When Things Burn?

ACTIVITY DETAILS

Time: 2 class periods (90-120 minutes)

Objectives

- Students will know that particulate matter (PM) is produced by combustion of fuels.
- Students will have an intuitive and a cognitive understanding of what PM 10 and PM 2.5 are.

Materials

- Candle & lighter/ matches (you may want 2 candles, a bigger one for the first demonstration and a smaller one for the oxygen demonstration)
- Glass jar &/or metal can with label removed
- Word wall words (soot, combustion, incomplete combustion, particulate matter (PM), particle)
- Flour & flashlight
- Orange (or match)
- Glass jar, aluminum foil, ice, paper, match (optional)

Handouts

- Notes sheet: What happens when things burn?

Activity summary: In this multi-part activity, students begin to investigate combustion by observing a candle burn and looking at the soot it produces. They read about particulate matter and experience a variety of different demonstrations to understand the difference between PM 10 and PM 2.5.

Standards Connection

SEP: Constructing Explanations
CCC: Cause and Effect

Warmup: Light the candle that you are going to use for the demonstration, and put it in a place where all students can see it. Have students describe what they see.

- Possible responses: It gives off light, there's something coming from the top, it's melting, it's burning, etc.
- The purpose of this warmup is to help prepare students for making observations that they will do later in the activity. Ask students what makes for a good observation (ex. it's detailed, clear and fully describes what you're observing)

1. **Frame the activity:** Display the truck picture(s) from the phenomenon (Activity 1) while the candle is still burning. Tell students that the candle and the trucks have something very important in common. See if any students volunteer the idea that they both burn things. If not, ask them what they see coming from both the candle and the truck. Use questioning to help them focus on the smoke/exhaust, and the idea these both come from burning things. Both the truck (diesel fuel or gasoline) and the candle (wax) are burning things. Tell students that to understand what's happening in our truck pictures, we need to understand what happens when we burn things, so they are going to study burning today.

2. **Candle burning observations:** Pass out the notes sheet "What Happens When Things Burn?" and tell students to record observations of everything they are about to see on the left side of the graphic organizer (Candle observations) with one observation per block. Relight the candle if necessary, and hold the glass jar or can above it so that it collects some soot (you may need to hold it very close to the flame). After you have collected enough soot, remove the jar/can and show it to students. You can also wipe some of the soot onto a paper towel and pass it around so students can see it. Make sure that students also observe the wick (is it getting shorter?)

3. **Candle burning discussion:** Once students have finished making observations, have them turn to a partner and share their observations. Encourage them to add each other's observations to their own sheets. Afterwards, have pairs share observations with the class, and keep a record using the board or chart paper. Common observations: the wax melted, black stuff came from the flame and got stuck to the jar, the candle wick stayed the same.
    - If students have missed key observations (see below) use questioning to focus their attention on these events
    - Ask students if they know what the black stuff is that they observed. If anyone uses the word soot, then put this word up on the word wall, and have them add the word on their observation sheets wherever appropriate.

4. **Constructing explanations:** In pairs or small groups, have students look at their observations, and think about what could explain each of the things that they see. Use an example to get them started: I observed the wax melting because the fire was hot and the heat caused the wax to melt. Using the structure, "I observed <blank> because <explanation>" can help students with their thinking process. Have them write their explanations on the right side of the graphic organizer next to the observation. Afterwards, have students share their explanations and add them to the chart of the observations. After each explanation, see if there is consensus among the class about whether the explanation is true. Support students in reaching accurate conclusions, but if they are stuck on something, tell them that they will come back to it later when they have learned more.

Observations	Explanations
The wax melted	The fire was hot and the heat caused the wax to melt
The jar has black stuff (soot) on it	The candle is burning and it makes soot that got on the jar
The candle wick stays the same	The wick is not burning
There is smoke coming from the candle	When the candle burns, it makes a gas

TEACHER NOTES

Safety First

- Whenever you plan to burn something in the classroom, be sure to have safety measures in place such as a fire extinguisher and fire blanket

Teacher Tip

✓ Make sure to try out the candle demonstration in advance. Some candles produce more soot than others, so you may want to try out a few different candles to find one that work well.

TEACHER NOTES

5. **Building vocabulary:** Tell students that scientists use special vocabulary to talk about burning. Put the words "**combustion**" and "**incomplete combustion**" on the word wall and ask if any students have heard the word combustion before. Explain that combustion is the scientific word for burning, and incomplete combustion is when something doesn't burn completely. Next put the words "**particulate matter (PM)**" on the word wall next to where soot is, and tell students that soot is a kind of particulate matter. It is called particulate matter because it is matter made up of small particles and it is abbreviated PM. Have students write definitions for these three terms on their notes sheets.

6. **Oxygen and combustion:** Light a small candle that you can put a glass jar over. Tell students that you are going to put the jar over the candle. Have them makes observations of what they see, then put the jar over the candle until it goes out. Like before, have students develop an explanation for this observation. Use questioning to help them reach the conclusion that combustion requires air/oxygen. Consider using the analogy of what would happen to a person if they were in a sealed room – eventually they would pass out from lack of oxygen.

7. **Summarizing combustion reaction:** Ask students what they think is needed for combustion. They should say air/oxygen (use this as an opportunity to clarify that combustion needs oxygen in particular, not just air). They may also say "a candle" or "wax." Help them to think back to the truck – does it run on wax? What word can we use to describe wood, gasoline, or wax – they are all fuels. Have students write oxygen and fuel in the "materials needed for combustion" box on the bottom of their notes sheet. Then ask them what they think is made from combustion. They should say soot and/or particulate matter. Have them write these in the "products of combustion" box. Ask if they know what the gases are in the smoke they saw coming from the candle. They may or may not know that carbon dioxide is the main gas. You can tell them that carbon dioxide and carbon monoxide are the main gases during incomplete combustion. Have them add these gases to the "products" box. Finally, tell students that hydrogen and oxygen are also products of combustion. They combine together: write H_2O on the board. See if students can identify this product (water) and have them write it on their sheets in the summary box.

Teacher Tip

✓ If students bring up the wick as something needed for combustion, ask them if the wick disappeared when the candle was burning. You can use this as an opportunity to have them think about what the wick is for in a candle.

8. **What burns?** Ask students what other things burn. Have them make a list in the space on their notes sheet. They will likely say things like wood, paper, matches, etc. Use prompts to help them think of other things: what burns in a stove (natural gas?) what burns in a grill? (propane or charcoal) what burns in a car? (gasoline). Have them add all these things to their notes sheet. Remind students that all combustion requires some kind of fuel.

9. **Turn & Talk: What is a particle?** Put the word "**particle**" up on the word wall, and have students turn to a partner to share what they think of as a particle. Use additional prompts as necessary (how big is a particle? What are particles made of? Can you give an example of a particle?). Afterwards, have students share out. Write down key takeaways for the group:
    - A particle is a very small part of something.
    - The word particle can mean a lot of different things – a particle of dust, an atom, or parts of an atom.

    After students share, point out that it's important when we use the word "particle" to be clear on what kind of particle we're talking about and how big they are, because there are many different kinds of particles.

10. **PM 10 and PM 2.5:** Tell students that scientists use the terms PM 2.5 and PM 10 to describe particles that are different sizes. Ask students what they think PM stands for (particulate matter) and which they think is bigger (PM 10). Have students look at the diagram on their notes sheet showing PM 10 and PM 2.5, and see what stands out to them. After they share, have them read the short paragraph below the diagram, and identify two similarities and two differences between PM 10 and PM 2.5.
    - Similarities: both are made of small particles, both are products of combustion, both are harmful to human health, both can be solid or liquid
    - Differences: PM 2.5 is smaller than PM 10, PM 2.5 can only be seen if there is a lot in once place, PM 2.5 can get into the human bloodstream, there are some differences in what PM 2.5 and PM 10 are made of (PM 10 includes dust, soot, pollen and various chemicals; PM 2.5 is mostly a chemical mix because it is usually smaller than dust and pollen)

11. **Demonstrating PM 10:** Prepare by taking a small amount of flour in your hand and turning off the lights. Have students prepare to observe, then toss the flour in the air and shine the flashlight on it. Ask students what they saw, and whether they think the flour is PM 10 or PM 2.5 (it is PM 10). Students should be able to see the flour particles.

TEACHER NOTES

Teacher Note

✓ The particle turn & talk is designed to activate student background knowledge. The key takeaways will be addressed in the next section.

Vocabulary tip

- Micron and micrometer are exactly the same unit of measurement. Micrometer is used in this module because it is the SI unit of measure and because students are likely more familiar with the prefix "micro-". Some diagrams (such as the one included on the student sheet) use the term micron, so you may need to clarify this for students.

Connection to Current Events

- Students may be interested in knowing how big coronavirus is compared to air pollution. One coronavirus is approximately 0.1 µm, which makes it much smaller than most PM 2.5.

TEACHER NOTES

Demonstration Safety

- Since breathing in PM 2.5 and PM 10 can be harmful, students should not breathe in the flour. Breathing in the scent from the match or the orange is not significant enough to cause harm.

Connection to Module 2

- Smog that causes a Code Red Day is the anchor phenomenon in Module 2. If you've taught this module with students, showing them how particulate matter and moisture can create smog (and not just ozone) may be a particularly interesting demonstration.

12. **Demonstrating PM 2.5:** Have students prepare to observe, then move to a corner of the room and either light a match and blow it out, or peel an orange. Have students raise their hands when they can smell the match or the orange. Ask them whether they think the scent particles from the match or the orange are PM 10 or PM 2.5 (they are PM 2.5). Students should be able to detect that there are particles by the smell, but they are too small to see.

13. **Demonstrating Smog (optional):** Prepare to create the demo by putting a piece of aluminum foil over a glass jar to make a lid. Take the lid off, and put ice on it to cool it down. In the meantime, put a small amount of water in the jar and swirl it around to cover the inside. Light a small strip of paper with a match and drop the paper and the match into the jar. Quickly cover the jar with the foil lid. Allow students to observe. (What happens is the combustion products combine with the cooled water vapor to create a hazy smog: PM2.5).

14. **Visualizing Particulate Matter (optional):** Show students the New York Time's visualization and article on particulate matter here: https://www.nytimes.com/interactive/2019/12/02/climate/air-pollution-compare-ar-ul.html. Use the graph feature to compare the amount of PM 2.5 in different cities around the US and the world.

15. **Formative Assessment:** Show students the pictures of the trucks from the original phenomenon (either the ones below or the ones you showed them) and remind them of the questions they came up with during their first activity about the trucks and their exhaust. Have them use the information on their notes sheet to answer at least one of these questions using accurate scientific terminology (ex. "what is truck exhaust made of?". You may want to remind students that not all products of combustion are visible.
    - Both PM 10 and PM 2.5 are coming from the truck. While the soot (PM 10) is visible, other chemicals that make up PM 2.5 are also likely present even though we can't see them.

Name _____

STUDENT HANDOUT

What Happens When Things Burn?

Candle	
Observations	**Explanations**

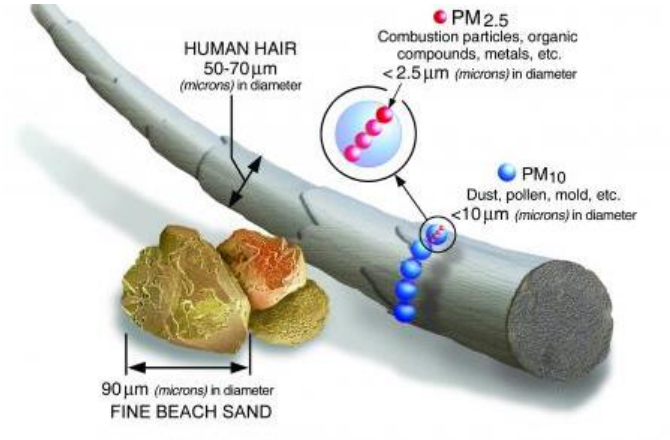
Combustion: _____

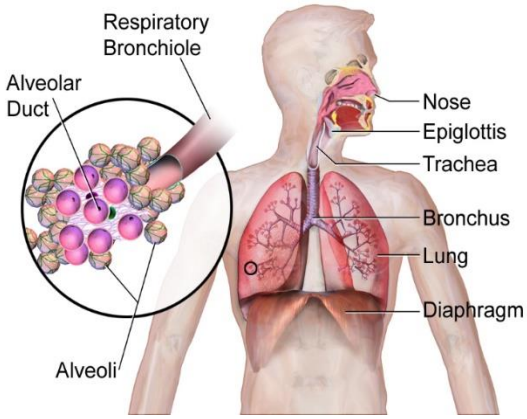
Incomplete combustion: _____

Particulate matter: _____

Materials needed for combustion	Products of incomplete combustion

What else is a fuel? What burns?





Reading

Particulate matter is one kind of air pollution that is a product of combustion. Large particulate matter or PM 10 is made of things like dust, pollen, soot and other chemicals. PM 10 is between 2.5 micrometers and 10 micrometers long. That is about one-fifth the width of a human hair. Small particulate matter or PM 2.5 is smaller than 2.5 micrometers. That means four particles of PM 2.5 are about the same length as one particle of PM 10. PM 2.5 is a mix of chemicals and metals that are very tiny. PM 2.5 is so small, you can only see it if there is a lot of it in one place. The funny symbol µ in the diagram above stands for "micro." One µm (micrometer) is 1/1000000th of a meter (one millionth) or 1/1000th of a millimeter. That's really small! Particulate matter can be a solid or a liquid, depending on the source of the pollution. All particulate matter is dangerous to human health when we breathe it into our lungs. PM2.5 is especially hazardous because it can go deep into the alveoli of our lungs and may even cross into our bloodstream and affect all parts of our bodies.

Name two similarities and two differences between PM10 and PM2.5

Similarities	Differences

Activity 3a (Explore): Measuring Particulate Matter Using Technology

Important Note About Activities 3a & 3b

There are two different methods students may use to measure particulate matter. Each is described below. You may choose to do one or both activities, although the content in the two activities is similar.

- **Activity 3a** (high tech). Students use commercially available PM meters and android tablets to measure particulate matter pollution in and around the school in order to identify sources of PM and areas that may be unsafe due to air pollution. They gather and analyze data in order to support claims about how safe the air is around the school.
- **Activity 3b** (low tech). Students use the engineering design process to design a low-tech particulate matter detector. They test out their models, and then deploy them into the field where they can gather PM that is deposited. Next, they gather and analyze the data from their detectors in order to support claims about how safe the air is around the school.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Analyzing Data

Activity summary: (see above)

Before starting this activity

- Read the information sheet: **AirBeams & AirCasting: How Does it Work?**
- Read the information sheet: **Using the AirBeam and AirCasting App** and familiarize yourself with how the AirBeam and AirCasting equipment works
- Setup stations for students to measure particulate matter indoors (ex. candle, incense, room deodorizer, etc.)
- Plan for any necessary chaperones for outdoor work on Day 2
- Add map of the school community (anywhere students may go for outdoor work) to the Day 2 data sheet: Measuring Particulate Matter in the School Community. If this isn't possible, you can have students write out their routes.

ACTIVITY DETAILS

Time: 2-3 class periods (90-180 minutes)

Objectives

- Students will be able to measure particulate matter using technology
- Students will be able to use their measurements to draw and support conclusions about how healthy the air is near the school

Materials

- AirBeams (approx. 1:4 students) These may be purchased or borrowed in partnership with Clean Air Partners (see sidebar below)
- Android device with AirCasting app
- Clipboards
- Computer & projector
- Student computers (optional)

Teacher Guides

- AirBeams & AirCasting: How does It Work?
- Using the AirBeams
- AirBeam Lesson Guide

Handouts

- Measuring PM in the Classroom
- Measuring PM in the School Community

TEACHER NOTES

Borrowing AirBeams

- Clean Air Partners has a class set of AirBeam PM monitors that can be used by students. Contact Clean Air Partners Education Manager Rebecca Davis (rnjidavis@gmail.com) to inquire about scheduling a visit from CAP staff.

Community Connection

- Take a moment to explain to students what a citizen scientist is, and how citizen scientists can contribute to the health of their communities

Modification Note

There are many different variations to how you might do this project, depending on your school grounds, availability of chaperones, etc. Consider what modifications, additions, or special preparations you may need to make based on your individual situation.

Warmup: What sources of particulate matter do you think there are near our school? (you can be broad with the definition of "nearby")

- Possible answers: schoolbuses (and other vehicles), construction sites (for dust), power/chemical plants that are upwind, wildfires, fields/trees that are producing pollen

1. **Frame the activity:** Tell students that now that they know the trucks in the pictures are emitting particulate matter, as citizen scientists it is their job to see if trucks or other sources of PM are making their own communities unsafe. For the next three days, they will measure and analyze the amount of particular matter in their community. Identifying and quantifying the sources of PM in a community is important so that community members can take action to protect their health and the environment.

   Due to the detailed directions required for using the AirBeams, a separate lesson guide follows. Below is an outline of the daily activities.

<u>Day 1 Outline</u>

1. Shows students how the AirBeam and AirCasting app works including a brief review of the internal workings of the device
2. Divide the class into groups and assign group roles.
3. Give each group an AirBeam and tablet to use and have them practice connecting the AirBeam and tablet using Bluetooth
4. Have students take measurements at various stations in the classroom
5. Using a Google Map of the school environment, plan routes where students can measure air quality at different locations during Day 2

Day 2 Outline

1. Refamiliarize students with the AirBeam equipment
2. Take students outside and lead them along their routes to collect data and make observations.
3. Return to class to analyze data and observations.

Day 3 Outline

1. Students complete analysis questions based on their data.
2. Students present their results to the class.
3. Students complete the “Conclusions” section of their data sheets including a Claim-Evidence-Reasoning argument.

AirBeam Lesson Guide

TEACHER GUIDE

Day 1

Note: Setup stations for measurements before class, but don't light any candles until students are ready to take measurements.

1. Tell students that for the new two days they are going to be collecting data with electronic devices called AirBeams that are paired with tablets (or smartphones).

2. Introduce the AirBeams and tablets to students by demonstrating how to turn on the devices and off, and how to connect them to the tablets (see "Using the AirBeam and AirCasting App")

3. Explain to students how the AirBeams work. Key points:
   - The AirBeams have a fan that pulls air into the device
   - There is an LED inside that shines a light on the air
   - The LED light is absorbed and scattered by the different sizes of PM
   - Sensors inside the AirBeam detect and measure the number of particles and their size by how much light is absorbed, and scattered

4. Divide the class into teams of four or more students depending on the number of instruments you have. Assigning roles to each member of the student team will help make sure all students are actively engaged. For Day 1, only roles 1, 2, and 4 are needed. For Day 2, all four roles will be needed. Each team member can be assigned one of the following roles:
   1) **AirBeam transporter**: makes sure the air beam is on and the air intake is clear and facing outwards. Stay within 10 feet of tablet.
   2) **Tablet carrier:** makes sure the tablet is connected, receiving and recording the data. Also takes photos of sources using tablet. Reads out the data for the group along the route.
   3) **Cartographer and timekeeper:** lead the team on agreed upon route. Identifies sources of pollution and makes notes on map
   4) **Data and note taker:** fill in the data table for # of sites agreed upon. Records observations.

5. Pass out AirBeams and tablets to each group. Make sure all group members know how to turn the AirBeam on and off, and how to pair it with the tablet. Remind students that the equipment is delicate and should be handled with care.

6. Pass out data collection sheets to students and review how they will collect data. The units of PM are $\mu g/m^3$. Explain to students how small a microgram is (one-millionth of a gram) and how big a cubic meter is.

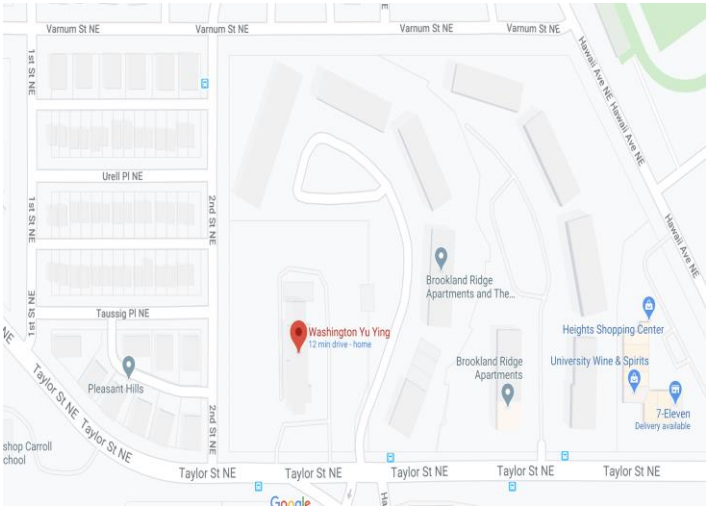
7. Finish setting up PM source stations. Possible stations include a candle, an air freshener (spray), chalk dust, incense, etc.

8. Have students rotate among the stations and collect data. As each team moves through the stations, they learn that commonly used items may release particulate matter. Have students switch roles at different stations so all students can practice using the AirBeam and using the AirCasting app on the tablet.

9. After the students have visited all the stations, have them return the AirBeams and tablets. Then have them review their data and answer the questions on their data sheets: What source emitted the most PM? Why do you think that is? What kind of PM was the most common? Why? Discuss answers with students afterwards. You can also ask additional follow up questions such as: what happened when you moved closer or farther from a source?

10. To prepare for the outdoor portion of the investigation, project a Google Map of the school community and/or pass out printed maps to students. Based on their warmup answers, and the research they have just completed, have students identify possible sources of PM on their school grounds or in the community. Common sources include the bus and car drop-offs, vents from the school (from an incinerator or HVAC system), or a busy street nearby.

11. Finally, have students develop an AirCasting route based on their understanding of where and when particle pollution might be elevated. Also consider where the pollution is going to be the lowest as a comparison point. Make sure students consider the time of day – will there be cars or buses idling out front? If not, can someone collect data when there are buses? You may have different classes or perhaps teams of students test air quality at different times of the day or in specific parts of the school grounds or community. Some students may agree to arrive at school early one day to test when the buses arrive in the morning or stay late in the afternoon when parents are picking up students. Pass out the "Measuring Particulate Matter in the School Community" data sheets to students, and have them draw or write their route on the sheet, with numbers showing where they will collect individual data.



Example map for planning AirCasting route

Day 2

1. Organize students into their groups, and make sure that all students know their assigned roles. If students will be traveling with a chaperone, have the chaperone introduce themselves to the students.

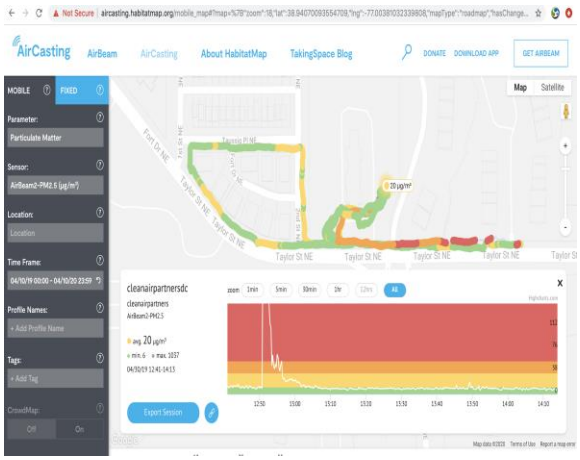
2. Make sure all student groups have their Measuring Particulate Matter in the School Community data sheets with their routes on them. Review what additional data students will collect while outdoors. They should use their various senses (sight, smell and hearing) and observe and note emission sources: ex: **mobile** sources such as moving cars, trucks, buses, a smoker AND **stationary** sources such as a vent, garage, nail salon. Note how close the source is to the sensor.

3. Hand out the AirBeams, tablets, and clipboards. Check to make sure all AirBeams and tablets are on and connected before going outside.

4. Take students outside to a central meeting location. If groups will be following different routes, make sure students and chaperones know what time they will meet back at the central location.

5. Students follow their agreed upon routes, collecting data as they go. When they have completed their routes, they return to the central meeting location.

6. When the student teams return to the classroom, have them upload the data to the AirCasting site (option crowdmap). If time permits, student teams should look at and analyze their data and be ready to share out their observation and results (otherwise this can wait until Day 3).



Sample data from the AirCasting website

7. Before the end of the class period, make sure to look up the PM2.5 levels for the area near the school. You can find this information by going to https://www.iqair.com/air-quality-map and using the map to find the nearest sensor. Be sure to record the PM2.5 level in µg/m^3 (not the AQI).

Day 3

1. Have students work with their groups to complete the analysis questions on their data sheets. Lead a short sensemaking discussion afterwards to clarify student thinking, especially around the idea of where the PM in the school community is coming from.

2. Project students' data from the AirCasting website, and discuss the data to clarify any questions they have.

3. Have student groups present the data they collected and share what they learned. Groups should share:
    - Where they went
    - What they found (ex. sources)
    - What their data was
    - What they learned from their data collection and analysis
    - Anything they would do differently next time

4. Have students complete the "Conclusions" section on their data sheets, and lead a short discussion afterwards to review conclusions.

5. The final assessment for this activity is the Claim-Evidence-Reasoning argument. You may have students do this in class or as a homework assignment. Especially if students are new to writing CERs, it is worthwhile to provide feedback on their responses and have them revise their responses to ensure that their final CER is high quality.

    Sample CER:

    - Claim: The air near the bus drop-off is the least healthy for people to breathe.
    - Evidence: The level of PM 2.5 near the bus drop-off was 42.5. This was the highest of all our measurements.
    - Reasoning: PM 2.5 can get into your lungs and your bloodstream, which can cause many different health problems. The EPA chart shows that the amount of PM 2.5 near the bus drop off was in the "unhealthy for sensitive groups" range which was the worst rating for all of our tests.

Name _____

STUDENT DATA SHEET

Measuring Particulate Matter in the Classroom

Connecting the AirBeam Sensor to the AirCasting App:

1. Turn on the AirBeam1. You'll know it's on when the red LED indicator begins blinking.
2. Turn on the android tablet or phone. Open the AirCasting app.
3. Press the menu button, then press Settings.
    - Press External devices, then select the AirBeam1 unique ID# (# will be on the AirBeam itself) from the list of paired devices. When prompted to connect, press Yes. You will then be redirected to the Sensors Dashboard.
4. In 5-20 seconds, measurements from the AirBeam will appear on the screen and the blinking red light on the AirBeam will switch to solid red. You're connected!

Data

Source (ex. candle)	PM 1.0 ($\mu g/m^3$)	PM 2.5 ($\mu g/m^3$)	PM 10 ($\mu g/m^3$)

Which source had the highest level of any type of particulate matter? _____

Why do you think this is? _____

_____

What kind of particulate matter (PM 1.0. 2.5, or 10) had the greatest amount? _____

Why do you think this is? _____

_____

Team Members: _____

STUDENT DATA SHEET

Measuring Particulate Matter in the School Community

My group's air testing route:

Insert Google map of the school community here.

Data

Location Number	PM 1.0 ($\mu g/m^3$)	PM 2.5 ($\mu g/m^3$)	PM 10 ($\mu g/m^3$)	Additional Observations Ex: school bus, vent, car, etc. how close is the sensor to the source?

Location Number	PM 1.0 ($\mu g/m^3$)	PM 2.5 ($\mu g/m^3$)	PM 10 ($\mu g/m^3$)	Additional Observations Ex: school bus, vent, car, etc. how close is the sensor to the source?

Additional observations:

How windy is it? _____

Temperature: _____°F Relative humidity: _____ %

Analysis Questions:

1. Was the PM level on your route higher, lower, or close to what you were expecting?

   _____

2. Where were particle levels highest? _____

   What is causing the PM level to be so high here? _____

   _____

3. Where were the particle levels lowest? _____

   Why do you think this was? _____

   _____

4. Do you think the time of day or season affected your results? _____

   Why or why not? _____

   _____

5. Where do you think most of the PM near the school is coming from? _____

   _____

Conclusions: How healthy is the air near the school?

When particulate matter levels get too high, they can be dangerous to our health. The chart below from the US Environmental Protection Agency (EPA) shows how healthy the air is based on the amount of PM2.5 and PM10. Keep in mind that these numbers are based on more than just one reading. They are based on the average amount of PM measured over a whole day.

	Good	Moderate	Unhealthy for Sensitive Groups	Unhealthy
PM 2.5	0 – 12.0 $\mu g/m^3$	12.1 – 35.4 $\mu g/m^3$	35.5 – 55.4 $\mu g/m^3$	55.5 -150.4 $\mu g/m^3$
PM 10	0 – 54.0 $\mu g/m^3$	55 – 154 $\mu g/m^3$	155 – 254 $\mu g/m^3$	255 – 354 $\mu g/m^3$

What is the PM2.5 level for the day you in your area (in $\mu g/m^3$) measured by the closest sensor? _____

You can find this information at: https://www.iqair.com/air-quality-map or by talking to your teacher

According to the chart, how healthy was the air? _____

How does the PM2.5 levels you measured compare to this? Are your readings higher or lower or a mix of the two?

_____

_____

Why do you think your readings might be different than the readings from the sensor? _____

_____

_____

_____

Write a Claim-Evidence-Reasoning argument about whether the air near your school is safe to breathe or not based on what you know about particulate matter. Make sure to use your data and the chart above to support your conclusion. You can choose to write about the area near the school in general, about specific areas near the school, or both.

Claim: Do you think the air is safe to breathe or not?

Evidence: What data do you have to support your claim?

Reasoning: What do you know about particulate matter that makes your claim true based on the evidence?

TEACHER GUIDE

AirBeams & AirCasting: How does it work?

The AirBeam is a palm-sized air quality monitor used to measure the amount of particulate matter in the air. Paired with an android device, and the AirCasting mobile app, citizen scientists, educators, students, and community leaders can take air quality measurements and contribute to a crowdsourced air quality map on the AirCasting website. Using the website, individuals can display and share air quality data.

The AirBeam uses a light scattering method to measure particulate matter (PM 1.0, 2.5 and 10). by drawing in air and measuring the concentration and size of particles using a light scattering method.

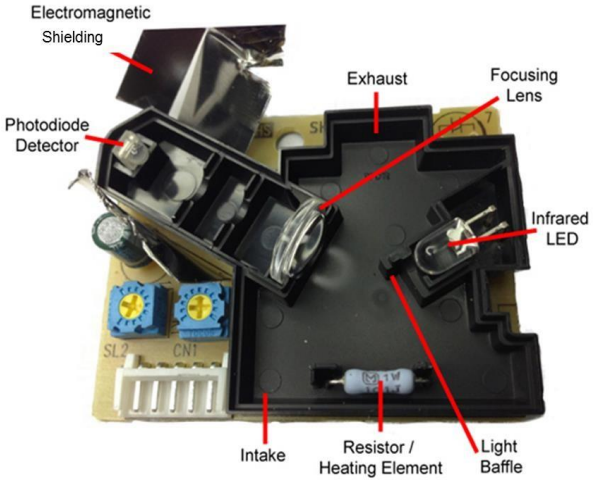


Image by Chris Nafas, modified by HabitatMap.

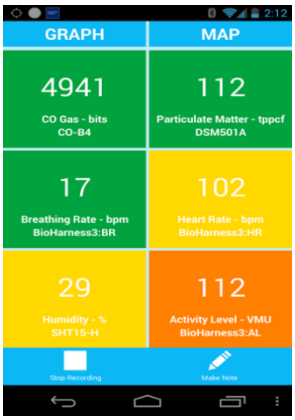
Once powered on, the AirBeam uses a small internal fan to create a partial vacuum which causes more air to flow into the AirBeams' "PM sensor intake". As the air is drawn through a sensing chamber, the infrared light from an LED bulb shines on the particles in the airstream. Some of this light is absorbed by the particles, and some is scattered. Two sensors inside the AirBeam: a particle-counting sensor and a light-scattering sensor, detect the number of particles and the amount of scattering. The information from the sensors is converted into a measurement that estimates the number of particles in the air (see below for more information on how estimates are calculated).

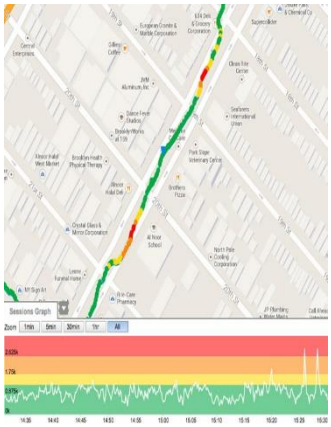
While the light scattering is related to the amount of PM in the air, the intensity of the light depends on a number of different factors.

- Amount of particles
- Size of particles
- Wavelength of light
- Angle of light scattering
- Number of particles
- Color of particles

The AirBeam takes measurements of PM 1.0, 2.5 and 10 in $\mu g/m^3$, as well as temperature and relative humidity. These measurements are taken once per second, and then communicated via Bluetooth to the AirCasting mobile app. The app maps and graphs the data in real time on your android smartphone or tablet. At the end of each AirCasting session, the collected data is sent to the AirCasting website, where the data is crowdsourced with data from other AirCasters to generate maps indicating where PM concentrations are highest and lowest.

An AirCasting session lets users capture real-world measurements, annotate the data and share it via the crowdmap on the AirCasting website. Using the AirCasting mobile app, AirCasters can record, map, and share 3 levels of PM concentration (1.0, 2.5, and 10), temperature, sound levels, and humidity.





* **Particulate Matter 1.0, 2.5 and 10 µg/m3:** Particles scatter light at an angle and intensity that is dependent on their size. When light strikes a particle, it is either diffracted, refracted, reflected, or absorbed. Smaller particles scatter light more intensely and at smaller angles than larger particles. Each particle size produces a unique scattering pattern. The intensity of light scattered is a function of its wavelength λ, scattering angle θ, particle size d_p, and relative index of refraction n between the medium and particle.

Photodetectors detect the intensity of scattered light. The energy of incident photons (elementary particle of light) on these devices cause electrons to be liberated. This produces an electrical signal (current) which is proportional to the intensity of detected light. This signal is converted into a measurement that estimates the number of **Particulate Matter 1.0, 2.5 and 10 µg/m3.**

Using the AirBeam & AirCasting App

Each AirBeam has a unique number that gets connected to the AirCasting App on the tablet to transmit the data. Once the AirBeam is connected to the tablet the data is transmitted every second and recording can take place. If the tablet is connected to WiFi the data will be visible on a map. If WiFi is not available, the data will be associated with a GPS location and will be placed on the map when uploaded to the AirCasting platform.

Connecting the AirBeam to the Android Tablet or Phone

Connecting the AirBeam Sensor to the AirCasting App:

1. Turn on the AirBeam1. You'll know it's on when the red LED indicator begins blinking.
2. Turn on the android tablet or phone. Open the AirCasting app.
3. Press the menu button, then press Settings.
    - Press External devices, then select the AirBeam1 unique ID# (# will be on the AirBeam itself) from the list of paired devices. When prompted to connect, press Yes. You will then be redirected to the Sensors Dashboard.
4. In 5-20 seconds, measurements from the AirBeam will appear on the screen and the blinking red light on the AirBeam will switch to solid red. You're connected!

Activity 3b (Explore): Measuring Particulate Matter Using Engineering

ACTIVITY DETAILS

Time: 3-4 class periods (180-240 minutes)

Objectives

- Students will be able to design, test, and deploy particulate matter collectors
- Students will be able to collect and analyze data to determine what areas of the school community have high levels of particulate matter in the air

Materials

- Magnifying glass or dissecting scope
- Graph paper
- Materials for building the detector (see materials section in step 4)
- Materials for testing the detector (ex. flour and pencil shavings)
- Scissors
- Additional paper for students to brainstorm and design

Handouts

- Design A Particulate Matter Detector

Activity summary: Students use the engineering design process to design a low-tech particulate matter detector. They test out their models, and then deploy them into the field where they can gather PM that is deposited. Next, they gather and analyze the data from their detectors in order to support claims about how safe the air is around the school.

Engineering Note

If students have not done any engineering in this class before, it is worth taking the time to teach them the engineering design process and to do a brief sample activity. Introductory information can be found at: https://www.teachengineering.org/k12engineering/designprocess. A good sample activity to do with students is the parachute design activity here: https://www.teachengineering.org/activities/view/design_a_parachute

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
DCI: ETS1.B: Developing Possible Solutions
SEP: Designing Solutions, Analyzing Data

Warmup: What sources of particulate matter do you think there are near our school? (you can be broad with the definition of "nearby")

- Possible answers: schoolbuses (and other vehicles), construction sites (for dust), power/chemical plants that are upwind, wildfires, fields/trees that are producing pollen

1. **Frame the activity:** Tell students that now that they know the trucks in the pictures are emitting particulate matter, as citizen scientists it is their job to see if trucks or other sources of PM are making their own communities unhealthy. During the next few days, they will design, test, and deploy devices to measure the amount of particular matter in their school community. Measuring the amount of PM in the community is very important to know whether people's health might be harmed from this type of air pollution.

Community Connection

Take a moment to explain to students what a citizen scientist is, and how citizen scientists can contribute to the health of their communities.

2. **Introduce the Engineering Design Challenge:** Hand out the "Design a Particulate Matter Detector" sheet to students, and read the problem and goal together with them. Make sure all students understand the purpose of the challenge. Next, review the criteria for the detector (A successful device must…)
    - Collect visible particulate matter (PM 10)
    - Limit the amount of non-particulate matter collected (ex. hair and dirt)
    - Include a method for measuring or counting the amount of PM collected (ex. using a magnifying glass and a grid for sampling)
    - Be able to survive intact outside for at least 2 days on its own

    Next, review the constraints for this challenge (A successful device can only…)
    - Use materials provided by the teacher or ones you can get from home
    - Take no more than two periods to build prototypes, test, and create TWO identical final versions for use in monitoring

    Take any time as necessary to answer students' questions about the criteria and constraints.

3. **Review testing procedures.** Explain to students how their monitors will be tested before being used in the field. There are several options you can use based on available materials, but in general, they should involve dropping sample particulate matter (ex. chalk dust or flour) on the detector, along with larger debris (ex. pencil shavings). A successful test means the flour gets in, the shavings are kept out, and there is a way to measure how much flour is on the monitor.

4. **Review materials**: Discuss the list of available materials with students, and review any additional rules for what students may bring in (ex. can they buy materials or do they have to be things they can find around the house?). Common materials students may want to use for their detectors are: paper plates, cardboard boxes and tubes, tape (regular and double-sided), petroleum jelly, string, glue, graph paper (to measure PM), note cards, duct tape, coffee filters, popsicle sticks, and pipe cleaners.

5. **Brainstorming ideas.** Form students into pairs, and have them begin by brainstorming different ideas for their designs on their handouts. if you think students will have a difficult time getting started, do this brainstorming as a class first. A good way to get students started is by having them think about how they can get the PM to stick to the detector. Write down options on the board.

TEACHER NOTES

Teaching Tip

- When reviewing the criteria, pause and consider places where the detectors might be placed. Include places where PM might be high (ex: bus drop off, parking lot) and low (ex. playground, field). Use students' answers from the warmup to support this discussion.

Timing

- The time for this challenge is flexible. Adjust based on length of class periods and how long students take to build and test their prototypes. It will likely take at least 2 class periods for students to go from initial design to final products.

TEACHER NOTES

Teaching Tip

- Make sure to have extra paper on hand for students to brainstorm or create designs.

Modification

- To help students minimize materials use, assign a value to each item (ex. double sided tape = $10 per foot) and give students a budget. They earn extra points on their design if they are under budget.

Documentation

- Documenting student progress through the engineering design process is a good way to show their learning progress. Take pictures of students, their designs, prototypes, and final products to help them reflect on their work later. This is especially helpful if students reuse materials from their prototypes in their final products.

6. **Creating designs:** Once students have a good set of ideas brainstormed, have them start designing their PM detectors on their sheets. Each part of their design must be labeled, and the design must address each aspect of the criteria. For example, make sure students have a way to sample the amount of PM (without trying to count it all) by using a grid. Check student designs and provide feedback. Try not to be judgmental – even if you think something won't work, let students try so they can learn on their own. Also make sure that students have written a way to measure the amount of PM in their monitor on their handouts. Suggested methods include putting a grid under their "sticky" material so they can count/measure the amount in a few grids as a sample. When a design looks good, allow groups to begin building prototypes.

7. **Building prototypes:** When a group has an approved design, they can take materials and start building. Be sure to control access to resources so one group doesn't take too much of one resource (see modification note on budgets for an option on how to do this).

8. **Testing prototypes:** As groups finish their prototypes, have them test using whatever protocols you have established. For example, shake flour through a sieve from 12 inches above the detector, and sprinkle pencil shavings from 12 inches above the detector. See if the prototype can keep the non-PM out and allow the PM in. Also check if students can count/measure the amount of PM in a quantitative way.

9. **Redesign and improvement:** As students make improvements to their designs and prototypes, support them by giving feedback and keeping them aware of time constraints. Try to avoid making suggestions, and instead ask questions to drive their design thinking. For example, "What materials could you use to help keep dirt out of the detector?" or "How can you use a grid to allow you to sample the amount of PM in the detector instead of counting it all?"

10. **Build final designs**: Once students have reached their final products, have them create two identical versions. This will allow them to compare results from two different locations in a valid way.

11. **Choose locations for monitoring:** As a class, choose locations around the school where the monitors will be placed. Try to avoid having the same pairs in the same locations (ex. If group A has their monitors in locations 1 and 2, then group B might have their monitors in locations 1 and 3). There should be at least two groups at each location to assist with comparative data analysis (see below). Have students record their locations on their handouts.

12. **Deploy monitors**: Put monitors out in their designated locations, and attach signs nearby indicating what they are and not to leave them alone. If you are concerned that monitors may be damaged by students, weather, etc., consider ways to avoid this, for example by putting them on a roof or on a high ledge. Leave monitors for at least one day. Check on them after 24 hours to see how they are doing. If results seem viable, bring them in; if not, try waiting an additional day or more. You can continue with the next activity in the meantime.

13. **Data collection.** Once monitors are ready to be analyzed, bring them back to the classroom and have students measure the amount of PM in each monitor using the method they have determined. While these measurements may not be completely accurate, they should be able to determine which of their two locations are better or worse in terms of PM.

14. **Data share:** Share data across groups to determine an order of best to worst location (see note on comparative data analysis). It may help to have students write their data on note cards so these can be sorted by location. Have students record the class data on their handouts.

15. **Analysis questions:** Have students answer the analysis questions on their handout based on the class data. Lead a short class discussion to clarify student thinking, with a special emphasis on where they think the PM in their school community is coming from.

16. **Formative assessment (Conclusion):** Have students answer the Claim-Evidence-Reasoning prompt on the last page of their handout. An example response might be:
    - **Claim**: The air near the bus drop-off is the least healthy for people to breathe, and the air at the playground is the most healthy.
    - **Evidence**: Monitors at the bus drop-off collected the most particulate matter compared to the other monitors around the school. Monitors at the playground collected the least.
    - **Reasoning**: If you breathe in high amounts of PM 10, it can get into your lungs and make breathing difficult. Because we collected the most PM 10 at the bus drop-off, that means the air there is the least healthy. We collected the least PM 10 at the playground, making the air there the most healthy.

17. **Reflection:** Have students reflect on the project, either through writing or discussion. If you took pictures during the project, share them with students. Some useful questions to ask are:
    - What did you like most/least about this project?
    - Was this project fun? Why or why not?
    - Did you ever get frustrated by your design? If so, how did you overcome your frustration?

TEACHER NOTES

Comparative data analysis

✓ Because students will have different designs, comparing data from one group to the next would be invalid. Instead, summarize the data within each student group (ex. site 1 has more PM than site 2), then use this information to establish which sites had higher and lower amounts of PM. For example, if Group A had more PM at site 1 than site 2, and Group B had more PM at site 3 than site 1, then it can be inferred that site 3 likely has the most amount of PM of the three locations.

Team Members_____

STUDENT GUIDE

Design a Particulate Matter Detector

Engineering Design Challenge

Problem: Particulate matter in the air can be damaging to human health if it is breathed in. PM 10 can irritate the lungs and cause respiratory problems. PM 2.5 can enter the bloodstream and cause health problems throughout the body. Because particulate matter is hard to see, a device is necessary to detect and measure it.

Goal: Work with a partner to design and deploy a detector for collecting and measuring the amount of particulate matter in the school community.

Criteria: A successful device must...

1. Collect visible particulate matter (PM 10)
2. Limit the amount of non-particulate matter collected (ex. hair and dirt)
3. Include a method for measuring or counting the amount of PM collected (ex. using a magnifying glass and a grid for sampling)
4. Be able to survive intact for at least 2 days outside on its own

Constraints: A successful device can only...

5. Be made of materials provided by the teacher or ones you can get from home
6. Take no more than two periods to build prototypes, test, and create TWO identical final versions for use in monitoring

Materials:

- Cardboard boxes and tubes
- Paper plates
- String
- Tape (regular and double-sided)
- Glue
- Graph paper
- Note cards
- Duct tape
- Coffee filters
- Popsicle sticks
- Pipe cleaners

Brainstorm ideas
Designs – don’t forget to label all parts of your design!

I will measure the amount of PM in my monitor by...
Data collection: Location 1: Location 2:
Data: Amount of particulate matter collected at Location 1: Amount of particulate matter collected at Location 2:
Class Data: Location with least PM: Location with most PM:

Analysis Questions

1. Was the PM level on your detectors higher, lower, or close to what you were expecting?

   _____

2. Where were particle levels highest? _____

   Why do you think this was? _____

   _____

3. Where were the particle levels lowest? _____

   Why do you think this was? _____

   _____

4. Where do you think most of the PM near the school is coming from? _____

   _____

Conclusion

Write a Claim-Evidence-Reasoning argument about what areas around your school have the cleanest or most polluted air based on what you know about particulate matter. Make sure to use your class data to support your conclusion.

Claim: What areas have the cleanest and the most polluted air?

Evidence: What data do you have to support your claim?

Reasoning: What do you know about particulate matter that makes your claim true based on the evidence?

Activity 4 (Explain): Particulate Matter and Human Health

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- Students will be able to identify the major health risks of particulate matter pollution
- Students will be able to compare and contrast the health effects of PM 2.5 and PM 10

Materials

- Sentence strips
- Student computers (optional)
- Computer & projector

Handouts

- The Health Effects of Particulate Matter

Teacher Tip

- If you have already done Module 1 with students, you can choose to skip this activity, or take a moment to refresh students' memories by replaying the Lung Attack Simulation.

Activity summary: In this activity, students learn about the major health effects of particulate matter pollution by engaging with a simulation and watching a video. They also determine what things they believed about combustion pollution are true and which are false.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
CCC: Cause and Effect

Warmup: Think back to the trucks we saw at the beginning of our investigation. How do you think the air pollution that comes from those trucks can affect our bodies?

- Possible answers: it hurts our lungs, it makes us sick, it makes us cough, it makes us sneeze.
- Tell students that in a moment you'll come back to these answers to see if they are true or not.

1. **Frame the Activity.** Ask students if any of them live near a busy road, or if they see a lot of trucks in their community. Have they ever wondered if the exhaust coming out of the trucks is harmful? Remind them of the videos they watched at the beginning of the investigation. What do they think it would be like if they were standing by the road when one of the trucks drove by? Tell students that in this activity, they'll learn more about how particulate matter affects the human body.

2. **Fact or Fiction:** Take students' answers from the warmup, and put them on sentence strips (or write them on the board). Tell students that they are going to decide which are facts and which are fiction. Ask them if they have any other ideas about what might be true or not about particulate matter.

   If students have not mentioned these, then add them to the list:
   - air pollution can get into our blood
   - air pollution can hurt your brain

   If none of the students' statements are false, considering adding something fictional like: air pollution can cause your skin to change color.

3. **Lung Attack:** Hand out the Health Effects of Particulate Matter notes sheet. Tell students that they are going to be watching a simulation that shows some of the health effects of particulate matter on the human body. As they watch, they should answer the questions on their handout.

If students are going to use computers to interact with the simulation on their own, then pass out computers and direct students to the Lung Attack Simulation: http://web1.pima.gov/deq/lungattack/lungplay.htm

If students will be watching the simulation together, project it so that all students can see and lead students through the simulations for PM 2.5 and PM 10.

After students have seen both the PM 2.5 and PM 10 portions of the simulation, take a few minutes to discuss their answers to the questions to clarify any misconceptions. They may have some gaps in the PM 2.5 portion of the notes sheet, which they will be able to fill in during the next video.

4. **How PM affects your brain (optional):** This video from UNICEF focuses on PM 2.5, so have students add additional notes from this video on that side of their handout. **Note:** some of the information in this video can be disturbing, so you may choose not to show it to students. If you do show the video, it is **highly recommended** that you stop it at 1:15 or 1:59. You may consider discussing students' reaction to the video after they have watched. The link to the video is here: https://www.youtube.com/watch?v=QcS3ovdsgNI

5. **Compare and contrast:** Have students answer the compare and contrast questions at the bottom of their notes sheet. Review their responses to clarify their understanding.
    - Similarities in health effects: both can affect the lungs causing difficulty breathing, coughing, and lung irritation
    - Differences: PM10 mainly affects the lungs and affects breathing. PM2.5 can enter the bloodstream, and cause effects throughout the body, including damage to the brain

6. **Return to Fact or Fiction:** Go back to students' statements from the beginning of the activity about the effects of air pollution from the trucks. Have them sort the statements by fact (true) or fiction (false). If there are some statements they don't yet know the answer to, you can leave them in undecided of give students a chance to look up the answers.

7. **Question check-in:** Take a moment to look back at the questions students generated during Activity 1. If there are any questions that you have answered, make sure to recognize this, and have students articulate a clear answer to the question. You may choose to use this in place of their formative assessment if appropriate.

8. **Formative assessment:** Have students answer the prompt: "Do you think the government should limit where combustion-powered trucks can go based upon what you learned today? Use evidence from your notes sheet to support your answer.

ACTIVITY DETAILS

Technology Note

- Lung Attack uses Flash player, which may need permission to run on your computer. Keep an eye out for a pop-up asking for permission for Flash player to run.

Alternative Media

- For an alternative video that is more comprehensive (and comical), show students the US National Library of Medicine's Video "Something in the Air: Particulate Matter and Your Health" found at: https://www.youtube.com/watch?v=zrHmD94F95A The video is long (20 minutes) so you may want to consider showing only a portion of it.

Teacher Tip

- This formative assessment is a teaser for the public health debate that will come at the end of the module

STUDENT HANDOUT

Name_____

The Health Effects of Particulate Matter

Particulate Matter 2.5	Particulate Matter 10
What is it?	What is it?
Examples:	Examples:
Where does it come from?	Where does it come from?
What happens when it gets in your lungs?	What happens when it gets in your lungs?
How does your body react?	How does your body react?
What part(s) of your body does PM2.5 affect?	What part(s) of your body does PM10 affect?

How are the health effects of PM2.5 and PM10 similar? _____

_____

How are the health effects different? _____

_____

_____

Activity 5 (Elaborate): Particulate Matter in the Community

Activity summary: In this activity, students analyze data based on real world studies of the health effects of living near a roadway. Through their data analysis, they are able to make connections between particulate matter and the health of an entire community.

Standards Connection

DCI: LS2.C: Ecosystem Dynamics, Functioning, and Resilience
SEP: Analyzing Data, Engaging in Argument from Evidence
CCC: Cause and Effect

Warmup: Where does particulate matter come from?

- Answer: power plants, fires, chemical plants, fields, vehicles, etc.
- This is a review of content they've learned previously to focus their attention on sources of PM for this lesson.

1. **Frame the activity:** Remind students that at the beginning of the last activity you asked if anyone lived in a neighborhood that had a busy road or a lot of trucks. Have them think about a community like that, even if they don't live in one. Imagine you live in a place where there is a lot of particle pollution. Ask students what they would do about it. They may suggest things like wearing a mask or staying indoors. Tell students that one thing people can do is act as citizen scientists, just like they did in Activity 3. Citizen scientists help study the problems in their community and come up with solutions to solve them. In this activity, they will study how particulate matter pollution can affect a whole community.

Community Health is Serious Business

During this activity students will investigate some serious topics (ex. cardiovascular disease) which they may have personal experience with. Be sure to address this carefully and with the sensitivity and seriousness that topics like this deserve. While the data they are examining is fictionalized, it is based on actual results from a variety of studies. See the accompanying documents for the sources used.

2. **Monitors vs. sensors:** Remind students of the particulate matter devices they used or built in Activity 3. Tell students that scientists use PM monitors that are permanently installed in different places to measure PM all the time. You can show them a picture like the one below. As citizen scientists, we can look up the data from these monitors if we want to know how high the air pollution is.

ACTIVITY DETAILS

Time: 1-2 class periods (60-120 minutes)

Objectives

- Students will analyze data in order to connect particulate matter pollution to health outcomes in a community
- Students will be able to distinguish between causation and correlation

Materials

- Computer & projector
- Student computers (optional for graphing)

Handouts

- Citizen Science: How Particulate Matter Pollution Affects a Community
- Graph paper

Teacher Tip

- In upcoming activities, students will be reminded of these monitors as a way to advocate for themselves (by having monitors installed)

TEACHER NOTES

This data from these monitors is more accurate than what we collected because the monitors are more sensitive and they are measuring PM all the time. You may also choose to show students this short video about the difference between personal sensors and EPA monitors: https://youtu.be/whP6CDWJ-fM. For their citizen science research, they'll be analyzing data that comes from monitors like this.

A particulate matter monitor in Kansas City, MO
Source: Missouri DNR

3. **Introduce the investigation:** Tell students that for their citizen science research, they are going to study how air pollution affects not just one person, but a whole community. Pass out the "Citizen Science: How Particulate Matter Pollution Affects A Community" handout. Have students look at the blank data table at the top. Ask students what things they see on the data table. Students should be able to pick out things like: major roadways, miles, cardiovascular disease, and asthma.

4. **Community health variables:** Ask students if they can identify the health outcomes that they will be looking at. They should recognize that the health outcomes are on the left-hand side of the chart. Review what each of these things means so students understand what data they will be looking at and what a "health outcome" is. Have them write their own explanations in the blanks on their handout.
    - **Cardiovascular disease**: heart/circulatory system disease (ex. high blood pressure, blocked arteries, etc.)
    - **Lung function**: volume of air you breathe in and out
    - **Emergency room visits due to asthma**: difficulty breathing, wheezing, coughing that requires an ER visit
    - **COPD (bronchitis/emphysema)**: difficulty breathing, coughing, wheezing that is persistent

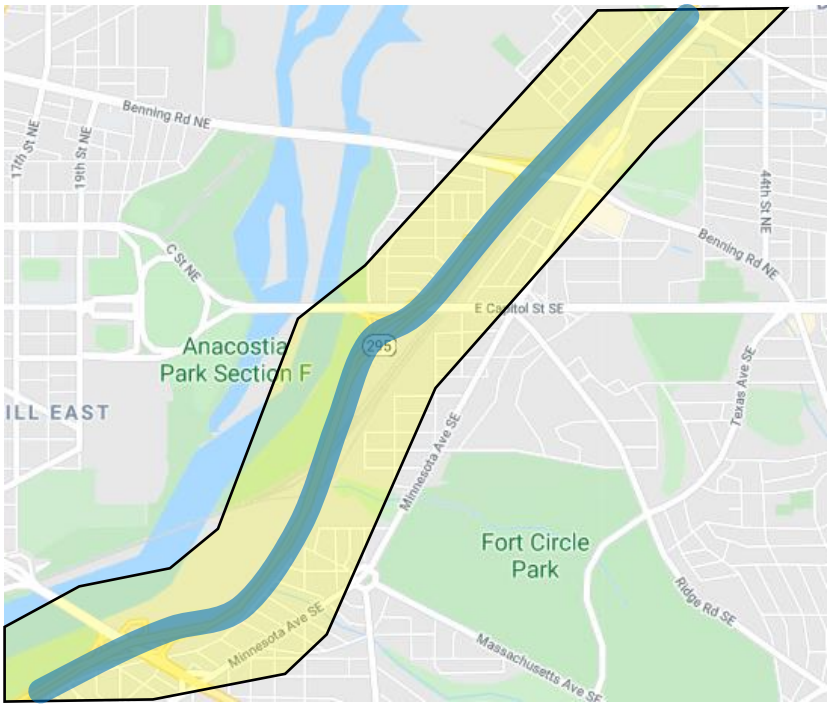
COPD (chronic obstructive pulmonary disease) vs. asthma

- COPD and asthma have similar symptoms. The main differences are that COPD tends to be an "all the time" chronic problem, while asthma is more likely to flare up due to triggers. COPD is more common in older adults, while asthma is more common in younger children.

Consider asking students if they know someone with one of these health issues. It is a good way to help make a personal connection, but be careful not to pry into personal health information.

5. **Areas of study.** Ask students what the different areas are that they are looking at with their data. Help them understand that they're looking at data in the area around a major roadway, starting from up to 200 feet away from the roadway, 200 feet to 1,000 feet away, and more than 1,000 feet mile away. Let's see what this means by looking at a map.

   Show students this map of Washington DC. The major roadway in this case is Route 295, which runs NE/SW through the middle of the map. The 200-foot distance from the roadway is in blue, and the 1,000-foot distance is in yellow. If you count the blocks, you can see that 200 feet from the road is less than a block. 1,000 feet is about 4 blocks.



   It is a good idea to show students the distance in their own neighborhood by displaying a Google map of the area. Right click on a major roadway, then choose "measure distance". Click anywhere else and you will bring up a measuring tool. Move the second point around to see how far 200 feet and 1,000 feet are away from the major roadway.

   Before sharing the data, ask students where they think people's health will be most affected vs. least affected. Make sure students get the general idea that health data nearest the roadway will likely be worst.

Asthma and roadway study in Baltimore

- For a comprehensive analysis of how air pollution affects asthma rates in Baltimore, see this study published in 2017: https://www.environmentalintegrity.org/wp-content/uploads/2017/12/Baltimore-Asthma.pdf

Research sources

✓ Research from many different sources went into the data shown below. For more information on some of the research sources used to generate the sample data, read the Introduction from the article: The Near-Road Exposures and Effects of Urban Air Pollutants Study (NEXUS): Study design and methods: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4243518/

TEACHER NOTES

Differentiation

- ✓ There are many different ways you can divide students into groups to analyze the data. Have students work in pairs to analyze all the variables, in groups to analyze all the variables. You can also have pairs analyze one variable and then have pairs share with one another. You can also choose different grouping methods for different students. Choose the grouping that works best to support all your students.

Differentiation

- When students are analyzing their data, they are only expected to find the difference between values. Depending upon their grade level, students may also be able to determine ratios between values, or to calculate rate of change. When calculating rate of change, consider the most logical value for x in these circumstances, since the distances vary from 200 feet to 1,000 feet.

6.Analyzing the data. Provide the students with the data that goes into the chart and have them add it to their sheets. Keep in mind that these are fictional data points based on actual research.

	People living within 200 feet of a major roadway	People living between 200 feet and 1,000 feet of a major roadway	People living beyond 1,000 feet of a major roadway
Cardiovascular disease rate	13.1%	10.4%	7.1%
Lung function in women (volume of air)	3,465 mL	3,477 mL	3,500 mL
% of children with asthma who went to the ER in the last year for asthma symptoms	75%	71%	51%
COPD rates (women)	9.1%	6.7%	5.1%

Have students analyze the data by answering the questions on their handout:

- Does the data you are looking at go up, down, or neither the FARTHER you go from the roadway?
- Does this mean the heath outcome gets better (healthier), worse (less healthy), or neither (no change)?
- How big is the difference?

7. **Graphing:** Have students create graphs showing the data. You can discuss with them what types of graphs to use. In this case, bar graphs work well. Line graphs are also possible, but be mindful of how to scale the x-axis based on the fact that the data points are at <200 feet, 200 feet-1,000 feet, and 1,000+ feet. If student computers are available, consider having students create the graphs on their computers.

8. **Causation vs. correlation:** Ask students whether they think that pollution from the roadway is **causing** the health **effects**. How do they know? Remind students that just because the data shows that people who live near roadways can have worse health outcomes, that doesn't mean the pollution caused their health problems. What other things from the road could be causing the health problems? (ex. noise). Is there any other reason people in the neighborhood might have health problems (ex. from a power plant in the area?). Proving **causation** (that the air pollution from the road is causing the health outcomes) is very difficult. It helps if they can explain how the pollution **might** cause the health problems.

Have students think back to the Lung Attack activity. What do they know about how particulate matter affects human lungs? How could they use this information to make an argument that the pollution is **causing** the health outcomes?

The key takeaway for students in the correlation/causation discussion should be that it may look like living near a roadway causes these health outcomes, but scientists would need to run more tests on the people to determine if their symptoms are **caused by** the air pollution, or by some other factor or combination of factors.

9. **Sensemaking discussion:** Discuss with students what their conclusions are based on these data. Use the CER below to help guide the discussion, being clear to consider the correlation vs. causation idea (based on these data health effects are correlated to living near a roadway, but we can't say they're caused by the pollution without more information.

10. **Question check-in:** Take a moment to look back at the questions students generated during Activity 1. If there are any questions that you have answered, make sure to recognize this, and have students articulate a clear answer to the question. You may choose to use this in place of their formative assessment if appropriate.

11. **Formative Assessment (Conclusions):** Have students complete the Claim-Evidence-Reasoning statement on the last page of their handout. Their CER should focus on how living near a roadway affects human health based on these data and other things they have learned throughout the module. Scaffold the CER as necessary based on students' experience with the structure. Students should keep a narrow focus on one health outcome. Example CER:

    - Claim: Living near a major roadway can be bad for your health, possibly because of pollution from cars and trucks.
    - Evidence: People who live within 200 feet of a major roadway have a 6-percentage point higher rate of cardiovascular disease than people who live more than 1,000 feet away from a major roadway.
    - Reasoning: Air pollution from cars and trucks can get into people's lungs and then into their blood stream. This can cause them to develop cardiovascular disease.

TEACHER NOTES

More on correlation vs. causation

✓ This discussion of correlation vs. causation is only a brief introduction. If you have taught the concept before, this is a good time to reinforce what you've taught before. If it's new to students (and you have more time) consider showing a video like this one: https://www.youtube.com/watch?v=VMUQSMFGBDo&t=205s

✓ If you plan to teach the other modules, Module 5, Activity 4 also discusses correlation vs. causation using graphs and a short reading.

Sensemaking

✓ For more tips on how to lead a sensemaking discussion, see "Sensemaking Strategies" in the additional materials that come with the curriculum or on this page from the On the Air 2020 website: https://www.ontheair.cleanairpartners.net/teaching-strategies

Name _____

STUDENT HANDOUT

Citizen Science: How Particulate Matter Pollution Affects a Community

Data

	People living within 200 feet of a major roadway	People living between 200 feet and 1,000 feet of a major roadway	People living beyond 1,000 feet of a major roadway
Cardiovascular disease rate			
Lung function in women (volume of air)			
% of children with asthma who went to the ER in the last year for asthma symptoms			
COPD (bronchitis) rates (women)			

What do each of these health effects mean?

- Cardiovascular disease: _____

  _____

- Lung function: _____

  _____

- Childhood emergency room visits for asthma: _____

  _____

- COPD (bronchitis/emphysema):_____

  _____

Analysis

For each variable, decide whether the data goes up, goes down, or neither the farther you get from the roadway:

- Cardiovascular disease: _____
- Lung function: _____
- Childhood emergency room visits for asthma: _____
- COPD: _____

For each variable, decide whether the health outcome gets better (healthier), worse (less heathy), or neither the farther away you get from the roadway. Remember, just because a number goes up or down doesn't mean it's getting better or worse:

- Cardiovascular disease: _____
- Lung function: _____
- Childhood emergency room visits for asthma: _____
- COPD: _____

For each variable, decide how big the difference in health outcome is between the 200-foot health outcomes and the 1,000-foot health outcomes (ex. what is the difference in the numbers?). Write the difference as a part of a complete sentence (ex. the cardiovascular disease rate is <blank> percent lower/higher at less than 200 feet away compared to 1,000 or more feet away.)

- Cardiovascular disease: _____

  _____
- Lung function: _____

  _____
- Childhood emergency room visits for asthma: _____

  _____
- COPD: _____

  _____

Create graphs of each variable using graph paper provided by your teacher, or use a computer to make your graphs.

Conclusions

Based on these data, and other things you have learned throughout this investigation, do you think that living near a major roadway poses a health risk to humans? Write a claim-evidence-reasoning statement to make an argument based on your research. Use the guide below to help with your statement:

> Claim: Your claim should answer the question about whether living near a roadway poses a health risk.
>
> Evidence: Your evidence should use data from the activity to support your claim.
>
> Reasoning: Your reasoning should explain how your evidence supports your claim. It should answer the question: how can living near a roadway affect a person's health? You will need to use information you learned earlier in the investigation for your reasoning.

Activity 6 (Elaborate): Air Toxics in the Community (optional)

Activity summary: In this optional activity, students learn about toxic air pollution, which can cause more acute health effects such as cancer. They do this by watching two videos showing real world examples of how air toxics have affected a community, and comparing the two situations. They also learn about how communities can advocate for themselves when air quality issues arise.

A Note About Activities 6 & 7

These optional activities explore two topics that are relevant to students in particular communities. Activity 6 explores hazardous chemical pollutants, and Activity 7 explores local pollution sources. If your school community is located in a place where pollutants - especially toxic pollutants - may be a concern, it is highly recommended that you take the time to do these activities with students.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems

Warmup: What does this symbol mean and where have you seen it before?

- Poison, danger, toxic (make sure students all know the word "toxic")
- On chemical bottles, on cleaning products, at a factory, etc.

1. **Frame the Activity:** Tell students that particulate matter from combustion vehicles isn't the only kind of air pollution that can be dangerous to a community. Today they are going to learn about two real world situations in which toxic chemicals affected a community, and what community members did to advocate for themselves when they found out there was a problem with air pollution.

2. **Air Pollution in Portland, Oregon:** Hand out the "Air Toxics in the Community" sheet for students to use to take notes on the videos. Have them take a moment to review the information they'll be collecting from the video. When they are ready, show the video: "How moss revealed an undetected air pollution threat in Portland" https://www.youtube.com/watch?v=jHy2qcxDLDM

ACTIVITY DETAILS

Time: 45 minutes

Objectives

- Students will learn how scientists identify sources of toxic chemicals in the community
- Students will understand the difference between the criteria pollutants and toxic chemical pollutants

Materials

- Computer & projector
- Speakers (for video)

Handouts

- Air Toxics in the Community
- Air Toxics and Criteria Pollutants

Vocabulary

- Air Toxics, toxic air pollutants, and hazardous air pollutants are all names for the same type of pollution.

TEACHER NOTES

Additional Media

- The Smokestack Effect Part 2 provides some additional information about local air quality testing and what individuals can do if they are concerned about air pollution and its effects on children: https://www.youtube.com/watch?v=KO_jz1RyQwk

Extension

✓ If students are interested in learning more about what chemicals count as air toxics, you can show them this list of the 187 hazardous air pollutants from the EPA: https://www.epa.gov/haps/initial-list-hazardous-air-pollutants-modifications While most of these chemicals will be unfamiliar to students, they will probably recognize things like chlorine, cyanide, and mercury

After the video, lead a brief discussion on what they learned about the air pollution problem in Portland, and what the community did about it.

- What are the toxic chemicals? heavy toxic metals (Cadmium, Arsenic)
- Where did they came from? Artisan glass manufacturing companies
- What were the health effects? Kidney damage, lung cancer
- Who first identified the pollution problem? US Forest service scientists (Sarah Jovan)
- How did they discover the pollution? moss had filtered pollution out of the air
- How did scientists studied the problem? analyzed moss samples from across the city
- How did the government follow up? set up air quality monitors
- How did the community respond (what did they do?): ask the state to setup air monitors, meet together, hold rallies/make signs

3. **Air Pollution in Addyston:** Tell students that they are about to watch another video of a community affected by air pollution. After this video, they will compare and contrast the two scenarios, so they should keep an eye out for similarities and differences as they watch. Show the video: "The Smokestack Effect: Part 1" https://www.youtube.com/watch?v=Zxm_-TxrhKI

   After the video, lead a brief discussion on what they learned about the air pollution problem in Addyston, and what the community did about it.

   - What are the toxic chemicals? They are not specifically named
   - Where did they come from? a local plastics factory
   - Health effects of the pollution: cancer
   - Who first identified the pollution problem? reporters from USA Today
   - How did they discover the problem? matching EPA data with school locations using a model
   - How did scientists study the pollution? set up air quality monitors
   - How did the government follow up? they issued orders to the company to change
   - How did the community respond (what did they do?): they closed the school

4. **Sensemaking:** Review students' answers to the questions about the second video, and then give them a chance to answer the compare and contrast questions on the next page. Once they are finished, discuss the similarities and differences between the two scenarios.

   Next, ask students how these videos made them feel. Were they concerned for the people in Portland and Addyston? How would they have reacted if they lived near a glass factory or if they went to school near a chemical plant? If students live near a major polluter like this, take the opportunity to help them make a personal connection to the communities in the videos (if you are not sure about major polluters in the area, students can look up that information in the next activity). Be sure to emphasize the actions that each community took to address the problem of air pollution.

5. **Air toxics vs. criteria pollutants:** Hand out the reading "Air Toxics and Criteria Pollutants." Give students time to complete the reading and fill in the Venn diagram. When they are done, discuss the differences to ensure student understanding.

6. **Formative assessment:** Have students answer the "What would YOU do?" questions at the bottom of the Air Toxics in the Community sheet. It is worth taking the time to review students' answers to these questions, as this topic will come back near the end of the module. It is also important for students to recognize that individual citizens have the power to improve the environmental quality of their communities if they have the right knowledge.
   - **Who would you talk to?** Parents, teachers, your doctor, government agency (ex. MDE, DOEE, VA DEQ)
   - **What would you ask them to do?** Set up air quality monitors in the community or near the suspected source; check to see if you or other people in the community have health problems that might be connected to the pollution
   - **What could your community do?** Talk to government officials and ask for an investigation; talk to reporters about the problem; hold protests or rallies about the pollution; have community meetings to teach others about the problem

TEACHER NOTES

Looking ahead

- In the next activity (Who is Polluting in My Neighborhood), students have a chance to look up whether there are air pollution sources in their community. If you plan to do that activity, be sure to have students look at the "Air Toxics" tab to identify if there are any sources of toxic air pollutants in their community. If you don't plan to do that activity, you may want to look up any sources on your own before this activity so you can share that information with students. If you do, be cautious and tactful – sharing information that there is a source of potentially harmful air pollution in the community is a serious matter and should be introduced thoughtfully.

Name _____

STUDENT HANDOUT

Air Toxics in the Community

Scenario 1: Portland, Oregon	Scenario 2: Addyston, Ohio
What are the toxic chemicals?	The specific names of the toxic chemicals are not mentioned in this video.
Where did they came from?	Where did they came from?
What are the health effects?	What are the health effects?
Who first identified the pollution problem?	Who first identified the pollution problem?
How did they discover the problem?	How did they discover the problem?
How did scientists study the pollution?	How did scientists study the pollution?
How did the government follow up?	How did the government follow up?
How did the community respond (what did they do?)	How did the community respond (what did they do?)

Compare & Contrast

What is similar the air pollution problems in Portland and Addyston?

What is different about the air pollution problems in Portland and Addyston?

What would YOU do?

If you believed there was toxic air pollution in your community, who would you talk to?

What would you ask them to do?

What kinds of things could your community do if they found out there was toxic air pollution?

Name _____

STUDENT HANDOUT

Air Toxics and Criteria Pollutants

What are Air Toxics?

Hazardous air pollutants, also known as toxic air pollutants or air toxics, are pollutants that cause or may cause cancer or other serious health effects. They may also cause damage to the environment. Toxic air pollutants are in things like gasoline and paint strippers. They are also used by different businesses such as dry cleaners. The US Environmental Protection Agency (EPA) is required to control 187 different hazardous air pollutants.

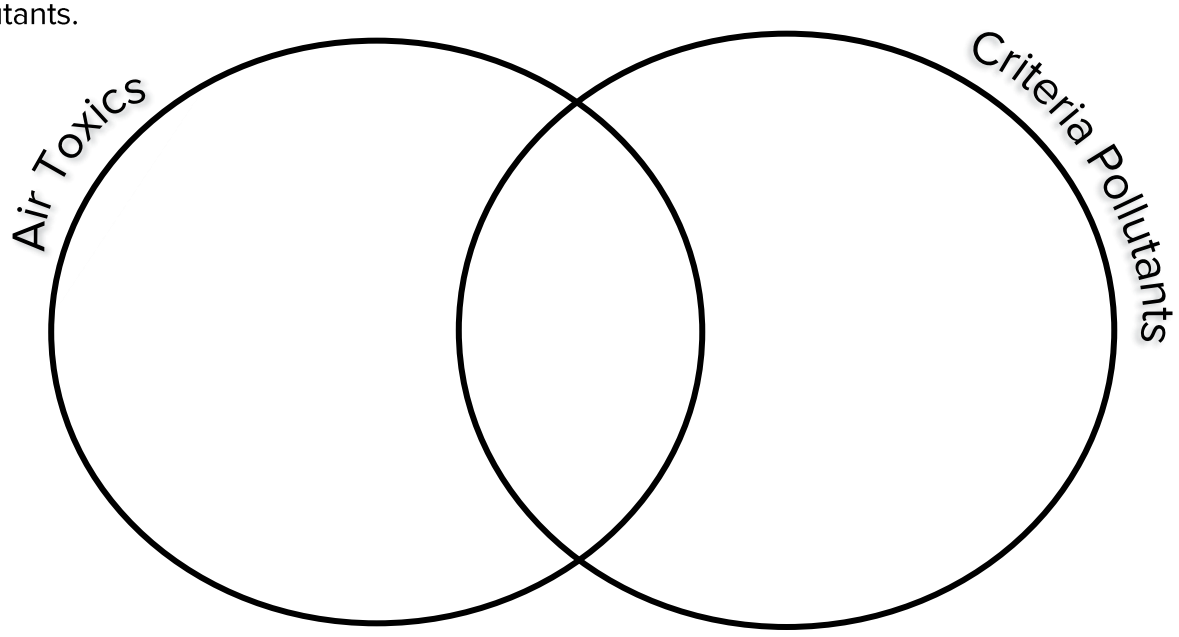
Where do Air Toxics Come From?

Most air toxics come from human-made sources, including mobile sources (e.g., cars, trucks, buses) and stationary sources (e.g., factories, refineries, power plants), as well as indoor sources (e.g., building materials and activities such as cleaning).

How are Air Toxics Different from Criteria Pollutants?

Criteria air pollutants are more common than air toxics, and they are less harmful in small amounts than air toxics. They are found all over the world, and they come from many different sources. There are only 6 criteria pollutants: particulate matter, ground-level ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, and lead. Like air toxics, the criteria pollutants can hurt human health and cause environmental damage, so they are also regulated by the EPA.

Fill in the Venn diagram below based upon what you know about air toxics and criteria pollutants.



Sources: Pollutants and Sources, US EPA**:** https://www3.epa.gov/airtoxics/pollsour.html
Managing Air Quality – Air Pollutant Types, US EPA: https://www.epa.gov/air-quality-management-process/managing-air-quality-air-pollutant-types

Activity 7 (Elaborate): Who is Polluting in My Neighborhood? (optional)

Activity summary: In this activity, students use a database to find local sources of air pollution. They identify who the polluters are, what type of industry they come from, what the pollutants are they emit, and how much. By comparing these data to other polluters, students can determine how much their local polluters contribute to air pollution in the community.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Analyzing Data

To do in advance: Use the local air pollution database to identify at least one local source of air pollution. You can access the database here: https://tinyurl.com/DCMetroAirPollution. Sort or search by zip code, town, or county to find pollution sources in your area. You can choose to use the tabs for criteria pollutants or air toxics, although students will mainly use the criteria pollutants for their investigation.

Warmup: Name four sources of air pollution.

- Transportation (cars, trucks, boats, planes, etc.), power plants, chemical plants, fires, etc.
- The purpose of this warm-up is to help focus students' attention back on sources of air pollution before they begin researching in their own community

1. **Frame the Activity**: Choose a major local source of air pollution from the research you've done beforehand. Try to choose something that students may have heard of or know about: this can be a power plant, a chemical plant, or a local manufacturer. Ask students if they've ever heard of the company or building. If you can find a picture of the building, show that to students as well. Ask them what they know about the source you've chosen. They may know where it is or what it does. Ask students if they know whether the source produces air pollution or what kind of pollution it makes. Tell students that it's important for members of the community to know if there are sources of pollution nearby and how dangerous they are. They already know that the trucks from their investigation contribute pollution to the community. Today they're going to research stationary (non-moving) sources of air pollution to see if they are affecting the community as well.

ACTIVITY DETAILS

Time: 30-45 minutes

Objectives

- Students will research air pollution sources in their communities and analyze their findings to think of ways to reduce air pollution in the community

Materials

- Computer & projector
- Student computers (highly recommended)

Handouts

- Air Pollution Sources in My Community

Modifications

- If student computers are not available, you can search for local pollution sources using the database and print out a set for students to use.
- The directions for the community database use zip code to find local pollution sources, but you can also use town or county. Check out the database in advance to know what search is best to use.

TEACHER NOTES

Source data

- ✓ The information for the local pollution source database comes from the National Emissions Inventory published by the US EPA. The database is updated every three years. These data come from the 2017 version of the database. Learn more about the NEI here: https://www.epa.gov/air-emissions-inventories/national-emissions-inventory-nei

Extensions

- ✓ There are all different ways students can interact with the database if you choose to take the time to teach them how to use Google Sheets. For example, they can filter by county to isolate local sources and then sort to see what industries are the greatest polluters in the area, or identify what pollutants are emitted most in their area. You can also have them use the Air Toxics tab to find hazardous pollutant emissions in the community and then Google their health effects.

2. **Community air pollution database:** Hand out the Air Pollution Sources in My Community sheet to students, along with student computers (if available). You may want to review the directions with students before having them begin the activity. You can also go through the first few steps with them to make sure they are on the right track. In general, students will search for information about local pollution sources, identify the kinds of pollution they are emitting, and how much.

3. **Analysis**: Have students answer the analysis questions to identify the type of industry and the pollutant that is most common in their area. They should also compare their local data to that of the biggest polluters in the database. For reference:
   - Electricity generation (power plants) is the largest type of emitter.
   - The most common pollutants from these sources are nitrogen oxides (NO_x) and Sulfur dioxide (SO_2).

4. **Discussion:** Give students a chance to share what they learned from their research. They may say they learned what industry is the greatest polluter in their area, or how much a local factory emits. Ask them questions about how this makes them feel. Were they surprised by the number of polluters in the area, or is their community relatively free of pollution sources?

5. **Question check-in:** Take a moment to look back at the questions students generated during Activity 1. If there are any questions that you have answered, make sure to recognize this, and have students articulate a clear answer to the question. You may choose to use this in place of their formative assessment if appropriate.

6. **Formative assessment:** Have students answer the following prompt: We know that transportation from cars and trucks like the ones we are studying, and also electricity generation are two of the biggest sources of air pollution. Why do you think these two sources of pollution are so big? What could you do to help reduce pollution from these sources? (Hint: what do you need every day that is transported from somewhere else?)
   - The goal of this formative assessment is to help students make the connection between human activities and air pollution. The reason these sources of pollution are so high is because we drive a lot, we transport a lot of things (food is the thing they use every day), and we use a lot of electricity. To shrink these sources, we can drive less, use less electricity, and eat locally produced food.

Name _____

STUDENT GUIDE

Air Pollution Sources in My Community

Directions:

1. Using your computer, go to the website: https://tinyurl.com/DCMetroAirPollution. You should see a spreadsheet of information that looks like this:

	A	B	C	D	E	F	G	H	I	
1	state	county	site name	facility source type	city	zip coc	pollutant desc	pollutant type(	total en	emissions unit of measure
681	MD	Baltimore city	CURTIS BAY	Rail Yard	Unknown	0	Nitrogen Oxides	CAP	91	TON
682	MD	Baltimore city	P Q Corporation		Baltimore	21230	Nitrogen Oxides	CAP	84	TON
705	MD	Baltimore city	Buckeye Terminals, LLC - Baltimo	Petroleum Storage Faci	Baltimore	21226	Volatile Organic Compounds	CAP	40	TON
706	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Carbon Monoxide	CAP	40	TON
730	MD	Baltimore city	BAYVIEW (NS)	Rail Yard	Unknown	0	Nitrogen Oxides	CAP	26	TON
745	MD	Baltimore city	PIER 7	Airport	BALTIMORE	0	Lead	CAP/HAP	20	LB
747	MD	Baltimore city	Buckeye Terminals, LLC - Baltimo	Petroleum Storage Faci	Baltimore	21226	Carbon Monoxide	CAP	20	TON
752	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Nitrogen Oxides	CAP	19	TON
766	MD	Baltimore city	Johns Hopkins Univ. - Charles Str	Institutional (school, h	Baltimore	21218	Nitrogen Oxides	CAP	19	TON
768	MD	Baltimore city	Crispy Bagel Company	Bakeries	Baltimore	21223	Volatile Organic Compounds	CAP	15	TON
793	MD	Baltimore city	CURTIS BAY	Rail Yard	Unknown	0	Carbon Monoxide	CAP	14	TON
799	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Carbon Monoxide	CAP	11	TON
803	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Carbon Monoxide	CAP	10	TON
804	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Carbon Monoxide	CAP	9	TON
823	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Nitrogen Oxides	CAP	9	TON
828	MD	Baltimore city	American Sugar Refining	Sugar Mill	Baltimore	21230	Nitrogen Oxides	CAP	8	TON

This is a list of all the pollution sources in Maryland, Virginia, Washington DC, and West Virginia. Make sure you are on the tab for Criteria Pollutants (look at the bottom).

2. To find pollution sources in your neighborhood, start by sorting the list by zip code. You can do that by clicking on the little triangle next to zip code that looks like this:

   Then click Sort A→Z. This will sort the list by zip code.

3. Now you can scroll through the list to find your zip code. You can also search for your zip code by holding <control>-F, typing your zip code into the box that pops up, and hitting enter. When you find some entries in the list for your zip code, go to the next step. If you can't find anything in your zip code, use one that has a similar number.

4. When you find some emissions sources in your zip code or one nearby, look in the column for "total emissions" (it is the next to last column). This is the amount of emissions that come from that source. Find the source with the most emissions in your area.

5. Write down the following information for that source in your data table on the next page:
   - **The site name**: this is the name of the company or organization
   - **Type**: this is what the company or organization does
   - **Pollutant**
   - **Total emissions**

6. Find at least four other sources of pollution in your neighborhood, and add their information to your data table. Look for sites you recognize from your neighborhood, and sites that have a lot of emissions.

Pollution Sources

Site Name	Type	Pollutant	Total emissions

Analysis

What "type" of polluter is most common in your area? _____

_____

What pollutant was most common in your area? _____

_____

Sort the database by total emissions by clicking the arrow next to total emissions and choosing "sort Z→A". When the database is sorted, look at the top 10 polluters.

What "type" of industry creates the most pollution? _____

What pollutants are most common from this industry? _____

_____

How do the polluters in your area compare to the biggest polluters? Do the emit a lot or a little pollution in comparison? _____

_____

Activity 8 (Elaborate): Not In My Backyard: Environmental Justice

Activity summary: In this activity, students investigate whether environmental injustice may be happening in their communities by using the EPA's EJ Screen Tool. They will examine a series of maps and graphs to compare pollution levels and demographics in these areas in order to reach their conclusions.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Analyzing Data, Engaging in Argument from Evidence

Warmup: What does justice mean to you? When have you heard the word justice used before?

- Focus on ideas such as equity and fairness. Students may have heard terms like "social justice" or "criminal justice" and they may associate justice with the legal system. The goal of this warmup is to help frame the discussion of environmental justice, but be careful not to let the conversation get too caught up in the complexity of what justice means.

1. **Frame the activity:** Ask students how they would feel if someone decided to build a new major highway through their neighborhood? Remind them that if we want to go places, then highways need to be put somewhere. What about a new power plant or factory? Did they ever wonder who decides where these things go, and how they decide where to put them? Write the acronym NIMBY (Not In My BackYard) on the board and explain what it stands for to students. Tell that that in this activity, they're going to look at some maps to see whether some people face more air pollution that others and if sources of air pollution like trucks on highways are fairly placed in our communities. We call this idea Environmental Justice. Put the words Environmental Justice up on word wall.

Low tech and High tech

For this activity, students will use maps from the EPA's online Environmental Justice Screen tool. If student computers are available, they will look up the information themselves. If computers are not available, you will need to have students look on the projector as you use the tool, or print out versions of the maps for students to use. The directions below are based on using student computers, but what students will do with the maps is essentially the same either way.

ACTIVITY DETAILS

Time: 60 minutes

Objectives

- Students will understand the concept of environmental justice
- Students will investigate environmental justice in their community to see if certain groups of people are more frequently affected by air pollution

Materials

- Computer & projector
- Student computers (highly recommended)

Handouts

- Environmental Justice investigation guide

Teacher Tip

- Make sure to go through the EJ Screen activity yourself before having students do it. The EJ Screen tool is relatively easy to use, but it is good to be familiar with the controls so you can help students.

TEACHER NOTES

Differentiation

- Some students may be comfortable following the directions right from their investigation sheet, while others will need more support. Choose the level of support for your students that works best for them. The directions as written here mirror what is in the student directions.

Accessibility Awareness

- EJ Screen uses colors for scale that will likely be difficult for colorblind students to see. You may want to pair any colorblind students with a partner to help with this. On some maps you can change the color coding; make sure to point this out as it will help as well.

Cultural Awareness

- EJ Screen uses the term "minority population" which carries some negative connotations. Students may also not be familiar with this term. You may want to discuss the term with them, including why it is or isn't used today.

2. **Introduction to EJ Screen (Student steps 1-2):** Pass out the Environmental Justice Investigation Sheet to students**.** Tell students that the EPA has a tool to help citizen scientists like them to determine if there is environmental injustice going on in their community. The tool is called EJ Screen. They're going to use EJ Screen to find out if there is environmental injustice in their community or others around them. Pass out student computers and have students go to the EJ Screen tool here: https://ejscreen.epa.gov/mapper/ Then have them type in their city/town or zip code in the box in the top right to center the map on their neighborhood.

3. **Particulate matter and ozone maps (Student steps 3-6):** Have students follow the directions for adding PM 2.5 to their maps. When they are done, they will write down the percentile that the neighborhood falls into for PM 2.5. The percentile related how the neighborhood compares in amount of PM 2.5 to other neighborhoods around the country. Note that the higher the percentile, the higher the amount of PM 2.5. After students have looked up the information, make sure to go over the concept of percentile with students, as it can be confusing. When students see the big red area for PM 2.5, they should have an idea that there might be a power plant or other major source of PM in that community. For ozone, they should recognize that ozone levels are high in the corridor between Baltimore and Philadelphia. This is likely due to high traffic volumes between these two cities.

What it Means to Investigate Injustice

The process of investigating injustice is both very powerful and at times very disheartening. As students look and possibly find environmental injustice, be mindful both of how this may affect them, and how it may empower them to advocate for change. This activity can have a tremendous impact on student thinking. Make sure that impact is one that honors their individual situation and teaches them how they can advocate for their communities.

4. **Demographics (Student steps 7-8):** When looking at demographics, students should notice that areas with high minority populations and high numbers of low-income individuals tend to be in or near major cities like Washington, DC, Baltimore, and Philadelphia.

5. **Side-by-side maps (Student steps 9-10):** When students are looking at the side-by-side maps of the Diesel PM and the Demographic Index, they should be able to see some overlap between these two maps, especially in places like SE Washington DC and Baltimore.

6. **EJ Indexes (Student step 11):** Many of the environmental indicators that students look at will show potential environmental injustice, often because the pollutants come from the same source. Ozone and Diesel PM are important because they are the result of trucks and other traffic that students are investigating in this module.

7. **Neighborhood reports (Student steps 12-13):** The reports tool can be especially valuable, because it allows students to look at all the indicators for one place at the same time. By looking at two different neighborhoods, they can see the big differences in the bar graphs for the environmental indicators. You may need to help students consider what neighborhoods to look at to see the differences. If you want to print out versions of these reports, click "Get printable standard report" instead of "Explore Reports" This will give you a nicely formatted report with the percentiles for EJ Index, demographics, and environmental indicators, as well as a map of the EJ Index.

8. **Sensemaking discussion:** Once students have finished their research, bring them together to discuss what they learned. Be sure to reference data that students explored, and to push them to use data to support their position on environmental injustice. Here are some questions you might use to guide the discussion:

    - What did you learn from this activity?
    - Do you think environmental injustice is real, and if so, is it happening in your neighborhood?
    - How does this information relate back to your own citizen science work in investigating the polluting trucks?
    - If there is environmental injustice happening, what can you do about it?

    For the last question above, consider what students have learned throughout the module (see activity 6 for advocacy ideas), and think ahead to what students will do in the last activity.

9. **Formative Assessment (Drawing Conclusions)**: Have students answer the prompt in the Drawing conclusions part of their guide: Do you think there is environmental injustice in the DC-Baltimore area? (do all people have the same amount of pollution in their communities?) Use at least three pieces of evidence from our activity today to support your answer.

TEACHER NOTES

Modifications

- There are many different things you can do with EJ Screen. This activity is just a beginning. If you have time, consider other ways you might use EJ Screen to teach about environmental injustice. You can look at specific neighborhoods, or look for sources of pollution in your neighborhood (ex. click add maps, additional layers, sites reporting to EPA. Check the box for toxic releases to see the sites that release toxic chemicals)

Environmental Justice Everywhere

- If environmental injustice is not happening where your students are located, but it is happening other places, think about how to help your students consider the idea that environmental injustice anywhere is environmental injustice everywhere. How can your students be advocates for environmental justice outside their own community?

Name _____

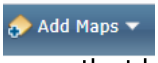
STUDENT GUIDE

Environmental Justice Investigation Guide

Directions:

1. Using your computer, go to the EJScreen website: https://ejscreen.epa.gov/mapper/

2. In the top right corner where it says, “Find an address or place” type in your city or town and click the name of the town when it pops up. You can also use your zip code for a closer map. You should see the map move to show your city or neighborhood.

3. Click the button at the top that says “Add Maps”. It looks like this: 

From the dropdown menu, choose EJSCREEN Maps. A box will pop up that has a list of many different maps to choose from. Since we are studying particulate matter from trucks, click PM 2.5 and click “Add to Map”.

4. The map you see now shows how the amount of PM 2.5 in your neighborhood compares to the amount in other parts of the country. Use the scale that popped up on the right side to match the color on the map with the percentile for your neighborhood. Write the percentile in the space below.

   PM 2.5 in my neighborhood:_____

   This means that your neighborhood has more PM 2.5 pollution than the same percent of neighborhoods around the country. For example, if your percentile is in the 80-90 range, then it means that 80-90% of the neighborhoods in the country have less PM 2.5 in their air than you do.

5. Zoom out by clicking the minus sign in the top left of your screen. Keep zooming out until you can see all of Maryland, Virginia, and Pennsylvania. Do you see a big red spot of PM 2.5 pollution near Harrisburg? What do you think might be there?

   _____

6. Change the map from PM 2.5 to Ozone by clicking Ozone in the box on the left and clicking “Add to Map”. Stay zoomed out so you can see the whole area. In what areas is ground-level ozone a problem?

   _____

   Why do you think it’s a problem here? (hint: think about what people do a lot of in this area that might cause a lot of air pollution)_____

   _____

   _____

7. In the box on the left-hand side, click “Demographic Indicators.” This will bring up a list of characteristics about people. Look at the maps for Minority Population and Low-Income Population. Where do you see high minority populations (people of color) and low-income populations?

---

8. Zoom back in on the area where your school is (you may need to put the town back into the search in the top right). What can you tell about the demographics of the neighborhood around the school?

---

9. At the top of the screen, click “Add maps” and then choose Side-by-Side maps. This will bring up two maps where you can look at different things at the same time. In the top left of the screen, click Map Data (it looks like this: Map Data ▼) and choose the Environmental Indicator for NATA Diesel PM. Then click Update Map. Diesel PM is particulate matter from vehicles like trucks that use diesel fuel. What do you notice about where Diesel PM is bad?

---

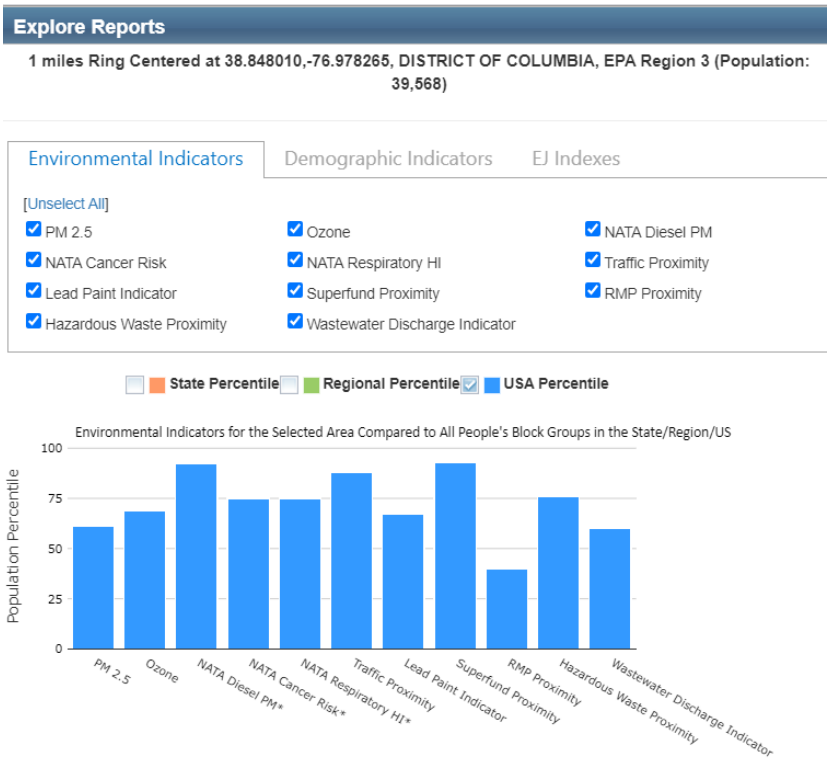
10. On the right-hand map, click the Map Data button, and make sure the top button is on EJSCREEN Maps. Then choose Demographic Indicators and Demographic Index, and click Update Map. Demographic Index shows where people of color and low-income people live. Make sure you are zoomed out so you can see the whole DC-Baltimore area. Compare the two maps. Where are the colors the same in both maps?

If the colors are in the sample places it means that people of color and low-income people live in places where there is a lot of air pollution. This is a sign of environmental injustice. Environmental injustice means that some people are affected more by pollution than others in a way that is unfair.

11. Go back to your original one map and in the pop-up on the left, choose EJ Indexes. EJ Indexes are like combining the two maps you just looked at into one map. If the colors on the map are in the yellow or red zone, it means environmental injustice may be happening in that community. Choose different pollutants for the EJ Index and click Add to Map. Which pollutants likely cause the most environmental injustice?

---

12. Use the location search in the top right of the screen to go back to the neighborhood where your school is. Then click the “Select Location” button at the top of the screen. Click Select Location again from the dropdown menu. A little box will pop up. Make sure the little pin is selected, and then click on the map near where you think the school is located. A little box will pop up. In the box, click “Explore Reports”. This will bring up reports about environmental justice in the area that look like this:



Look at the data in the bar graphs. This shows the percentiles for all the pollution within 1 mile of the pin you put in the map. What are the highest pollution indicators near your school?

Click where it says EJ Indexes in the reports box. This shows whether there is likely to be environmental injustice in the area near your school. The higher the percentiles, the higher the risk of environmental injustice. Based on the percentiles, do you think there is environmental injustice happening in your community? If so, write down the EJ Index for the pollutants you think show environmental injustice may be happening.

13. Move the map to a different neighborhood that you think may be different than yours. Do the same thing you did with your neighborhood: click select location, then put a pin in that neighborhood and click Explore Reports from the box that pops up. Look at the environmental indicators for this neighborhood. How do they compare to the indicators in your neighborhood?

Click on the tab in the reports box that says EJ Indexes. What are the indexes like here compared to in your neighborhood? Do you think environmental injustice is happening here?

Drawing conclusions

Based on your research today, do you think there is environmental injustice in the DC-Baltimore area? (do all people have the same amount of pollution in their communities?) Use at least three pieces of evidence from our activity today to support your answer.

Activity 9 (Evaluate): Public Hearing on Banning Diesel Trucks

ACTIVITY DETAILS

Time: 2-3 class periods (120-180 minutes)

Objectives

- Students will explore and learn different perspectives on public policy related to air quality
- Students will make arguments based on evidence about whether or not diesel trucks should be banned in the community

Materials

- Role play stakeholder cards (print out and cut up enough so each student has one)
- Student computers (optional for research and writing statements)
- Research materials
- Presentation rubric
- Final Vote writing rubric
- Stakeholder cards

Handouts

- Diesel truck ban role play scenario
- Role-play planning
- Hearing notes sheet
- Cast your vote writing prompt
- News article about California's ban on diesel truck manufacturing (optional): https://arstechnica.com/cars/2020/06/california-set-to-ban-all-heavy-diesel-trucks-and-vans-by-2045/

Activity summary: In this multi-day final activity, students take on the roles of different stakeholders in order to participate in a state committee hearing on whether or not to ban diesel trucks from traveling through residential communities. After taking on a role, they use their notes and additional resources to research their position. Next, they write a statement for their character. Finally, they hold the hearing, with some students acting as committee members who ask questions, and others reading their statements.

Standards Connection

DCI: ESS3.C: Human Impacts on Earth Systems
SEP: Engaging in Argument from Evidence
CCC: Cause & Effect

Warmup: The stakeholders for a school are the students, teachers, administrators, parents, the government, and interested community members. Based on this list, what do you think a "stakeholder" is?

- Use responses to help students understand that a stakeholder is someone who has an interest in a particular thing like a business, a policy, etc. That interest is usually based on the fact that it affects their lives in some way – ex. how they earn a living, their health, their future, etc.

1. Frame the activity: We have spent the last week (or more) studying air pollution in a community, especially air pollution that comes from vehicles like trucks. We studied particulate matter and how it can affect people and a community. Now it is your chance to raise your voice about what we should do about the trucks and the air pollution they create. During the next two days, we are going to role play a fictional scenario of a government hearing to decide if diesel trucks should be banned from traveling through residential communities. First you will learn about all the different stakeholders, from people in the community to truck drivers. After we have learned about our roles, you will hold a meeting to decide whether or not the trucks should be banned. Everyone will participate in the meeting based on the role that you have.

2. Introduce the scenario: Share the role play scenario with students and read it together. Make sure all students understand the details of the scenario. Students should immediately start making connections with what they have learned throughout the module. Do your best to answer any questions students, and feel free to improvise as necessary.

3. **Identifying stakeholders:** Ask students what stakeholders they think would be involved in this scenario. Give them a moment to write down a list on their scenario sheets. When they are ready, have students share their ideas, and write them on the board. Use questioning and discussion techniques to help them think of a robust list of potential stakeholders, especially different people that work in the shipping industry or that ship their products with trucks. Also consider everyday citizens, and government officials of the cities, towns, and counties in the state.

   Once the stakeholder list is created, tell students that they will each take on the role of one of these stakeholders for this activity. They will have time to learn about their stakeholder, and do some additional planning and research to think about what their stakeholder might say at the meeting.

4. **Assigning roles:** Give each student a role card from the scenario (or have them choose one). If any roles you identified earlier in the activity are not on a card, allow students to choose that stakeholder as well. Have students share their role with the class so they all know what roles they are playing. Make sure the State Committee Members know that they will be the ones listening to the other stakeholders during the meeting (they will not write statements).

5. **Researching roles:** Hand out the Role Play Planning sheet, and give students time to develop their characters by:
   - Giving themself a name
   - Talking to other people with similar roles or others who may be able to provide information for them. For example, citizens may want to talk to the health researchers or the environmental scientists
   - Deciding if they want the committee to vote for or against the ban
   - Doing research on diesel trucks (see handout for details)
   - Creating a written statement that they will read, or points that they would like to make, including their position.
     (Note: Committee members should create questions to ask the other stakeholders during the meeting.)

6. **Writing statements:** Once students have finished their research, have them write a statement from their character's point of view. Encourage them to think of what arguments their character would make, either in favor of or against the ban. They should use information from their research to support their statements.

TEACHER NOTES

Differentiation

✓ Consider what roles may be easier or more difficult to play for individual students, and assign those roles accordingly.

Advance planning

- You may want to have some resources available to assist students with their research including articles (see materials) or websites. Remind students to look back in their notes for information as well. A fact sheet from the Maryland 2015 Strategic Goods Movement Plan is attached and may be helpful to some stakeholders

Getting into the role play

- Consider different ways that you can help students get into their roles. For example, you may get name tags and have students put their fake name and role on the name tag so they can more easily identify one another.

TEACHER NOTES

Modification

- ✓ If you have a large class, consider having students with similar roles work in pairs to deliver a joint statement.

Modification

- ✓ Instead of (or along with) having some students act as committee members, have experts on the topic (ex. government officials, researchers, etc.) join the class for the hearing to act as committee members.

7. **Preparing for the hearing:** The day of the hearing, the teacher will play the role of a state official who will run the meeting but who does not have a vote at the end. Before starting the meeting, make sure all students are prepared to participate (they have notes, a prepared statement, etc.) Arrange the classroom so that the committee members can sit facing the rest of the class. Provide a place for stakeholders to speak from. You may want to create a sign-up sheet so that you can call on stakeholders when it is their turn. Hand out the notes sheet to students and tell them that they will be writing their own letter or decision (whether or not to ban the trucks) after the meeting, so they are required to take notes during the meeting on reasons for or against the ban.

8. **Hold the hearing.** Call the meeting to order, and provide a brief statement about what the meeting is for. Tell stakeholders that they will come up to the podium, tell everyone their name and what their role is, and then make their statement. Committee members may have questions for them. A government official (the teacher) will keep track of time.

   During the meeting, you may choose to use the rubric below to assess students on their statement, including their answers to questions that the council members ask. If necessary, you can prompt the council members to ask questions, or you can ask yourself. Keep time to make sure the meeting moves forward and all students have a chance to present. Council members can be assessed based on how well they ask appropriate questions and interact with the presenters.

9. **After the hearing:** Thank all the students for their participation in the committee meeting. Tell them that they will have the next period (or more) to write their final statement about whether the permit should be approved or not (see next activity). They should write the statement from *their own perspective*, not the perspective of their characters. After all the assignments have been turned in, they will tally the votes to see whether the permit is approved or not.

10. **Casting their votes:** Provide students with the final writing prompt to do either in class, or at home. The writing prompt asks students to vote for or against the ban, and then use evidence from the committee meeting and the rest of this investigation to support their decision. Their evidence should include:
    - What particulate matter is and how it affects the human body
    - Where particulate matter comes from
    - Any additional details required to support your argument for or against banning diesel trucks from residential neighborhoods

Review the prompt with students, and review the writing rubric with them (it is very similar to the presentation rubric). You may choose to allow them to use their committee statements to help them write their final vote statements – the committee statement will work well as a first draft.

TEACHER NOTES

Tallying the Votes

✓ Don't forget to tally the votes at the end of the module to let the students know the results of their hearing!

STUDENT GUIDE

Diesel Truck Ban Role Play Scenario

Scenario: The state government has been studying the problem of particulate matter pollution, and has decided that they should do something about it. After listening to different stakeholders, they have decided to consider a new law to ban diesel trucks from traveling through residential neighborhoods in the state by 2030. To consider this proposal, they will hold an open public meeting where different stakeholders will share their opinions with the state government committee. After the meeting they will vote on whether to move the bill forward.

Stakeholders:

The Committee Meeting:

- The state is considering a new low to ban diesel trucks from driving through residential neighborhoods in the state by 2020. The State Government Committee of Environment & Transportation is holding a hearing to get public comments before they vote on for or against the bill. Stakeholders are encouraged to attend to the meeting to provide input into the decision.

Name _____

STUDENT GUIDE

Role Play Planning

What is your character's name? _____

What is his/her role? _____

Do you want the committee to vote for the ban or against the ban?_____

When doing your research, consider your role. What kind of information should you know? Here are some questions to consider researching:

- How many diesel trucks are used in the state?
- What alternatives are there to diesel trucks?
- How much do diesel trucks cost? How much would this alternative cost?
- What can the state do to help make this cost lower?
- Why kind of air pollution do diesel trucks emit?
- What are the health effects of this pollution?
- What is the effect of this pollution on the environment?

My Statement (or questions for committee members):

Remember to consider your role, and to use evidence to support your argument.

Name _____

STUDENT GUIDE

Hearing Notes Sheet

Reasons to ban diesel trucks	Reasons NOT to ban diesel trucks

Student Name_____

Diesel Truck Ban Presentation Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Factual accuracy	Student's statements have significant factual inaccuracies.	Student's statements have some factual inaccuracies.	Student's statements are factually correct, but do not always support their argument well.	Student's statements are factually correct and support their argument well.
Argumentative speaking and writing	Student does not present an argument that supports their position and is not supported by evidence.	Student presents an argument that does not support their position well, or is not supported by evidence.	Student presents a thoughtful argument in support of their position. Argument is supported by some evidence	Student presents a thoughtful and compelling argument in support of their position. Argument is well supported by evidence.
Alignment to role	Student's position and argument is not at all aligned with their role	Student's position and argument is not well aligned with their role	Student's position and argument is mostly aligned well with their role.	Student's position and argument is aligned well with their role.
Answering questions	Student cannot answer questions about their argument.	Student struggles to answer questions about their argument.	Student is able to answer questions about their argument.	Student is able to answer questions about their argument, and use evidence to support their answers.
Craftsmanship	Student's statement has numerous grammatical errors, and is not delivered smoothly.	Student's statement has some grammatical errors, and may not be delivered smoothly.	Student's statement is well-written, with few grammatical errors. Their presentation may not be delivered smoothly.	Student's statement is very well-written, with few or no grammatical errors. Their presentation is delivered well.

Stakeholder cards

Product Manufacturer Works for a manufacturing company that ships all of its products out using diesel trucks. Sometimes those trucks travel through residential neighborhoods to get to his customers. Has two kids and is concerned about their health from any air pollution	Student Teenager with asthma who lives near a major highway. Concerned about the health effects from air pollution on her ability to play outside and walk through her community.
Truck Driver Owns his own diesel-powered truck that he uses for his job. Knows that he will not have enough money to switch his truck to another fuel like hydrogen, or to battery power.	Mayor of Metro City Knows that a lot of the businesses in Metro City rely on diesel trucks to get products to sell, and to send out products they make. Knows that a lot of the residents of Metro City care about the environment and having clean air to breathe.
CEO of Truckville Shipping Company Runs a very large fleet of diesel trucks. Knows it will cost a lot of money to switch all of their trucks from diesel to another fuel like hydrogen, or to battery power.	Citizen scientist in Metro City Used EJ Screen and learned that particulate matter is especially high in her neighborhood, which is next to the highway Cares about environmental justice for herself and her neighbors.
Pleasant County Council member Wants Amazon to build a new warehouse in the County. Knows that Amazon currently uses a lot of diesel trucks to ship its products around the country.	Pleasant County Council member Cares about the environment of Pleasant County and is concerned about how air pollution from the trucks is already affecting the county

Health Researcher	Environmental scientist
Can provide information about the health effects of air pollution on children, adults, and the elderly Cares about providing information more than siding with one opinion	Can provide information about the environmental effects of air pollution Cares about providing information more than siding with one opinion
State committee member	Concerned citizen
Cares about protecting the state environment Cares about protecting the health of state residents Cares about the helping trucking companies do business in the state because it provides jobs for residents and taxes for the state.	Orders a lot of things online, including groceries, clothes, and cleaning supplies. Is worried that if the cost of shipping goes up, the cost of all the products will also go up to cover the extra shipping cost.

2.0 MULTIMODAL GOODS MOVEMENT NETWORK

Businesses in Maryland generate products that are shipped throughout the world while simultaneously demanding goods that are produced across the globe and shipped to Maryland. Domestic and international goods move through the Port of Baltimore or other seaports in the US, BWI/Marshall Airport or other airports in the US, and by truck or rail. Maryland's goods movement transportation network is composed of the State's highway network, freight rail network, air cargo airports, waterways, seaports, and intelligent transportation systems.

Logistics networks often span thousands of miles over land, sea, and air, and require critical multimodal connections. At a state level, Maryland's logistics network includes freight shippers and receivers, freight handling facilities, waterborne freight terminals, and air cargo facilities. The highway and rail networks provide vital connections between generating, receiving, and handling facilities.

Maryland's goods movement transportation network is comprised of 32,372 public road miles, 758 rail miles, 530 inland waterway miles, and over 50,000 feet of air cargo runways. Together, these modes moved nearly 631 million tons of freight worth $835 billion, in 2012, the most recent year of available data. By 2040, more than 1 billion tons of freight worth close to $1.6 trillion, is expected to move within and through Maryland. This section describes the components of each of these networks, including the locations of key links and nodes along with an overview of performance indicators.

Table 1: Percent of Shipments by Domestic Mode, 2012 Weight and Value

Mode	Total	Within Maryland	From Maryland	To Maryland	Through Maryland
Truck Tonnage	83.9%	96.4%	92.0%	56.7%	84.6%
Truck Value	97.7%	97.9%	93.7%	94.4%	99.3%
Rail Tonnage	12.8%	0.5%	5.1%	42.2%	11.1%
Rail Value	0.9%	<0.5%	0.7%	3.2%	0.5%
Domestic Water Tonnage*	<0.5%	<0.5%	<0.5%	<0.5%	0.0%
*Domestic Water Value**	<0.5%	<0.5%	<0.5%	<0.5%	0.0%
Domestic Air Tonnage**	<0.5%	<0.5%	<0.5%	<0.5%	0.0%
*Domestic Air Value***	0.5%	<0.5%	2.0%	1.5%	0.0%

*Domestic water includes shallow draft, deep draft, Great Lakes, and intra-port shipments, but does not include international waterborne trade through the Port of Baltimore. The domestic (landside) moves of Port of Baltimore trade are accounted for in other modes.

**Domestic air includes air cargo between U.S. and domestic origin-destination pairs. The domestic portions of international air cargo movements are accounted for in the appropriate domestic modes.

Source: Maryland 2015 Strategic Goods Movement Plan: http://www.mdot.maryland.gov/newMDOT/Freight/Documents/Strategic%20Goods%20Movement%20Plan.pdf

Name _____

STUDENT GUIDE

Cast Your Vote!

Now that you have heard arguments for and against banning diesel trucks from traveling through residential neighborhoods, it is time for you to cast your vote. Imagine YOU were on the government committee making the decision. You will need to provide evidence supporting why you voted one way or another.

Your statement should use evidence from the committee meeting and the rest of this investigation to support your decision. Your evidence should include:

- What particulate matter is and how it affects the human body
- Where particulate matter comes from, including why it comes from diesel trucks
- Any additional details required to support your argument for or against banning diesel trucks from traveling through residential neighborhoods

My vote (circle one): FOR the ban AGAINST the ban

My statement:

Student Name _____

Diesel Truck Ban Final Vote Rubric

Project area	Beginning	Needs Improvement	Proficient	Advanced
Factual accuracy and completeness	Student's statement has several factual errors or is missing most relevant details about what particulate matter is, how it affects the human body, and how it relates to diesel trucks.	Student's statement has some factual errors and includes some relevant details about what particulate matter is, how it affects the human body, and how it relates to diesel trucks.	Student's statement is factually correct and includes most relevant details about what particulate matter is, how it affects the human body, and how it relates to diesel trucks.	Student's statement is factually correct and includes all relevant details about what particulate matter is, how it affects the human body, and how it relates to diesel trucks.
Argumentative writing	Student does not present an argument that supports their position and is not supported by evidence.	Student presents an argument that does not support their position well, or is not supported by evidence.	Student presents a thoughtful argument in support of their position. Argument is supported by some evidence	Student presents a thoughtful and compelling argument in support of their position. Argument is well supported by evidence.
Craftsmanship	Student's statement has numerous grammatical errors, and is not delivered smoothly.	Student's statement has some grammatical errors, and may not be delivered smoothly.	Student's statement is well-written, with few grammatical errors. Their presentation may not be delivered smoothly.	Student's statement is very well-written, with few or no grammatical errors. Their presentation is delivered well.

Doing Our Part

- Find ways to use less electricity: turn off electronics when you're not using them like TVs and game consoles. Turn off the lights when you leave a room or when you leave the house.

- Buy local products that were made in the United States so there is less transportation. This is especially true of food. Food that is "in season" can usually be grown from nearby states so there is less transportation involved.

- Talk to your school leaders about creating an idle-free zone at the bus and car drop off. This means that cars and buses must turn off their engines when they stop to pick up and drop off students.

- Look up anti-idling campaigns in your area of other ideas on how to prevent particulate matter pollution from idling vehicles. For example, check out Idle Free Maryland: https://mde.maryland.gov/programs/Air/MobileSources/idlefreeMD/Pages/index.aspx

- Look up the local particulate matter air quality (AQI) using a computer or install an air quality app on your phone or your parents' phone. Use the AQI so you know when and how to avoid air pollution, especially on bad days.

- Avoid places where you know the air quality is likely to be bad, such as near roadways with lots of traffic (especially big trucks) or near power, cement, and chemical plants that are in your neighborhood. When walking to school, choose a route that stays away from busy streets.

- If you sometimes have difficulty breathing, talk to your parent(s) or doctor so they can make sure you get the help you need.

About this section

This section in included in every module either as a list or as part of an activity. It describes actions students can take to mitigate the effects of air pollution in their lives, and to help prevent air pollution from getting into the atmosphere. Many of these suggestions are the same from module to module, but there are variations depending on the focus of the module.

While the actions from this section are not explicitly built into the curriculum, they can be used in various ways to motivate students and provide them opportunities to take action to make a difference in their community. For more information, see the "Doing Our Part" section in "How to Use this Curriculum"

Air Quality Champion in Our Community

Name: Joshua Shodeinde
Title: Regulatory and Compliance Engineer
Organization: Maryland Department of the Environment

How does your work relate to air quality?
I work in the Air Regulations Development Division at the Maryland Department of the Environment (MDE). MDE's mission is to protect and restore the environment for the health and well-being of all Marylanders. I work with a team of engineers who write air regulations (rules) that air pollution sources such as power plants or manufacturing facilities have to follow. These rules help to ensure that the air we breathe in Maryland is healthy and safe.

What is your workday like?
My daily tasks vary from day-to-day. One day I may share ideas with other regulators on rules to reduce pollution, on another day I may meet with businesses to help them understand a regulation. Sometimes, I read and learn about sources of air pollution and what needs to happen to improve air quality. I really enjoy the variety of my job.

What motivates you to come to work every day?
My biggest motivation is knowing that my work is directly involved with improving air quality. I used to have asthma growing up, so working in a field where I can help reduce toxic air pollutants and potentially reduce asthma attacks has a personal connection to me. I also have a young daughter who I want to grow up strong and healthy. I want her to have a love for nature and outdoor activities like taking walks or biking or hiking. Working to protect Maryland's air quality will allow my family and millions of others in the state to enjoy the great outdoors without worry.

What education and career path did you pursue to have the position that you have today?
I graduated college with a Bachelor of Science degree in Chemical Engineering. My first real job was working at a nonprofit organization, whose mission is to strengthen Baltimore's communities through education, skills development, and community service. This job taught me the importance of environmental and energy stewardship, a fancy way of saying that we should all act responsibly to protect Maryland's air, land, water, and energy. We can do this by turning off lights when we don't need them; riding our bikes and using public transportation whenever possible; not wasting water and food; and recycling. My role was to educate Baltimore residents about energy conservation and provide them with energy-saving items. Next, I worked at a company that helps business owners to upgrade their lighting to energy-efficient lights. Then I came to work at MDE.

What is your workspace like?
I work in an office cubicle, which has a table, file cabinets, and a desktop computer. I have pictures of my wife, daughter, and former colleagues in my cube. I enjoy going on walks with colleagues during break time (there's a park right beside our building) or talking about shows in the break room.

What accomplishment are you most proud of?
For work, I would say my biggest accomplishment has been writing two regulations which aim to reduce greenhouse gas emissions. It was a lot of work that required coordination with other staff at MDE, businesses, environmental advocacy groups, and concerned citizens. I remember the day I had to give a 3-hour presentation, with a question and answer session, on why these greenhouse gas regulations are important. With the help of my bosses and colleagues, we received support from everyone to move ahead with the regulations.

For my personal life, it is raising a 2-year-old. Kids are also lot of work! But I love her dearly and seeing her grow is so rewarding.

Is there something important that you want to share that we haven't asked?
I would just add that you don't need to work for an environmental agency to fight against air pollution and fight for improving air quality. Every day there is opportunity to play our role to help protect, preserve, and restore the environment. Play your part!

Glossary

air toxics - pollutants that cause or may cause cancer or other serious health effects, such as reproductive effects or birth defects, or adverse environmental and ecological effects. Also known as toxic air pollutants or hazardous air pollutants

AQI (Air Quality Index) – a scale for reporting daily air quality. The AQI tells you how clean or polluted the air is in a given location, and what the associated health risks are. The AQI focuses on health effects you may experience within a few hours or days after breathing polluted air.

arsenic – an element that occurs naturally in Earth's crust, and is commonly found in water, air, and soil. In high enough quantities or in the case of long-term exposure, arsenic can cause significant health problems

cadmium – an element that occurs naturally in Earth's crust. Cadmium can be released to the air as a result of industrial processes. Inhaling cadmium fumes can be highly hazardous to health.

cardiovascular disease – a health condition that involves narrowed or blocked blood vessels that can lead to a heart attack, chest pain, or stroke.

combustion – the chemical process of burning. Combustion requires a fuel that is burned using oxygen in a chemical reaction that produces carbon dioxide and water. See also incomplete combustion

COPD (chronic obstructive pulmonary disease) - a group of related diseases that cause airflow blockage and breathing-related problems. COPD includes emphysema and chronic bronchitis.

diesel – a type of fuel made from oil that is used in specialized combustion engines (diesel engines) where it is ignited through compression as opposed to a spark in more common combustion engines

environmental justice – the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income, or any other personal characteristic with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.

incomplete combustion – a type of combustion that takes place when the supply of oxygen is poor. This results in a higher proportion of carbon monoxide gas and solid carbon (soot) being produced instead of carbon dioxide. Water is still a product of incomplete combustion.

lung function – a term used to describe how well the lungs work in helping a person breathe. Lungs function is measured by lung size, air flow, and other aspects of lung health.

micrometer/micron (symbol: μ) – a unit of length equal to one-millionth of a meter (0.000001 m). Micrometer is the SI unit of measure, while micron is the former name of the unit which is still in common use.

ozone (O_3) – a natural and a man-made gas made of three oxygen atoms that occurs in the Earth's upper atmosphere (the stratosphere) and lower atmosphere (the troposphere). Depending on where it is in the atmosphere, ozone affects life on Earth in either good or bad ways.

particulate matter (abbreviation: PM) **–** a mixture of solid particles and liquid droplets found in the air. Some particles, such as dust, dirt, soot, or smoke, are large or dark enough to be seen with the naked eye. Larger particles are called PM 10, smaller particles are called PM 2.5, based on their diameter in micrometers.

soot – a black powdery or flaky substance consisting largely of amorphous carbon, produced by the incomplete burning of organic matter including fossil fuels.