CARTEEH
CENTER FOR ADVANCING RESEARCH IN
Transportation Emissions, Energy, and Health
A USDOT University Transportation Center

What is in the air?

Introducing Air Pollution for Grades 5-8

Released March 29, 2022

CARTEEH

Table of Contents

Lesson Plan Overview

This unit was developed through a partnership between the Center for Advancing Research in Transportation Emissions, Energy, and Health (CARTEEH) (https://www.carteeh.org/) and Texas A&M University's Teaching Learning & Culture Department.

Center for Advancing Research in Transportation Emissions, Energy, and Health
A USDOT University Transportation Center

TEXAS A&M UNIVERSITY
Teaching, Learning & Culture

CARTEEH brings together experts from multiple disciplines that have not traditionally worked together including transportation, public health, and energy sectors**.** CARTEEH focuses on the impact of transportation emissions on human health. CARTEEH is a Tier-1 center, funded by the U.S. Department of Transportation's Office of the Secretary for Research and Technology under the University Transportation Centers program. The Texas A&M Transportation Institute leads the CARTEEH consortium, consisting of four partner universities: Johns Hopkins University, Georgia Institute of Technology, University of Texas at El Paso, and the University of California, Riverside. Members of the CARTEEH consortium strongly advocate for advancing research on transportation emissions in a more comprehensive manner and mapping the holistic tailpipe-to-lungs spectrum, which includes the impact of transportation emissions on the environment and public health.

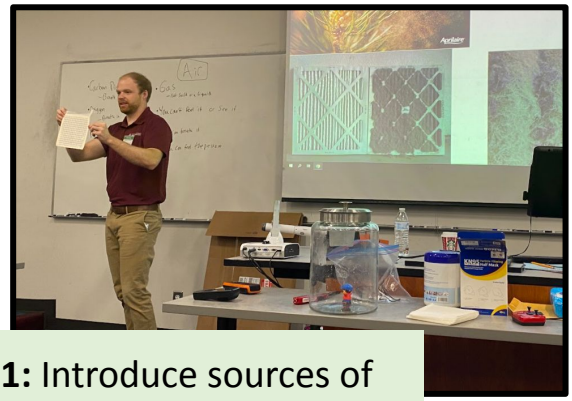
Lesson Description

Many people are unfamiliar with the serious environmental problem of air pollution compared to other issues like anthropogenic climate change. However, in 2016 the World Health Organization attributed 4.2 million premature deaths to unhealthy air quality worldwide. Air quality challenges are likely to become more exacerbated as populations, transportation, and energy demands continue to grow. This sequence of lessons is designed to promote a deep understanding of this critical issue, including the scientific knowledge and societal decision-making facets. Each lesson draws on the extensive science education research base to foster a logical flow, questions, and activities that promote a high-quality and meaningful learning experience for students.

Learning Objectives

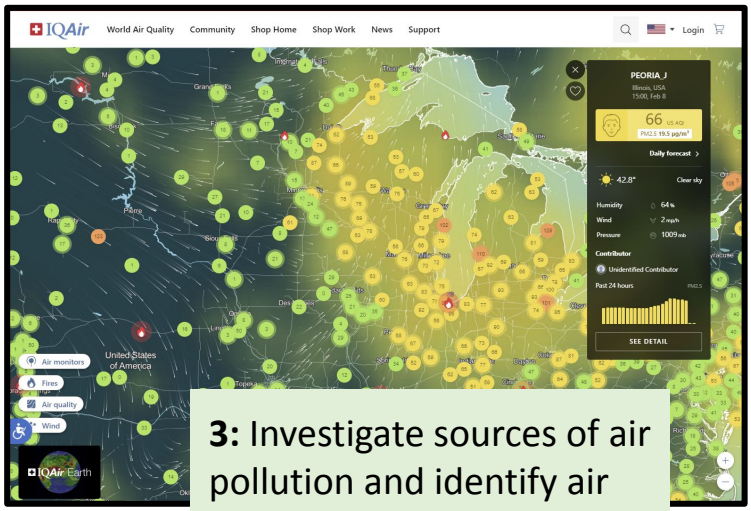
1. Promote a deep and robust knowledge of the air pollution environmental issue.
2. Build an accurate understanding of the airborne particles we breathe, including the types of particles, the sources of various particles, and the health and environmental impacts of different particulates. The focus is on particulate particles.
3. Stimulate civic decision-making using reasoning and scientific evidence to generate resolutions and actions that can positively impact the environment.

Lesson Plan Overview

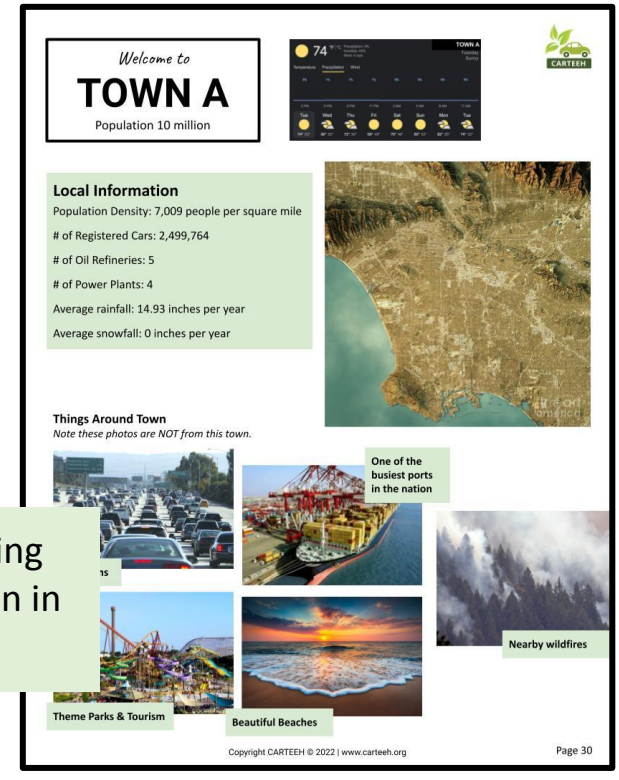


1: Introduce sources of air pollution and gather prior knowledge.

2: Conduct an investigation to measure and identify sources of air pollution around the school and community.



3: Investigate sources of air pollution and identify air quality levels around the world.



4: Apply knowledge by identifying potential sources of air pollution in a *Mystery Town* activity.

What is in the Air?

The following lessons follow an overarching learning cycle to build a deep and robust understanding of concepts related to air pollution by first allowing students to explore through concrete experiences followed by concept development and a chance to apply the concepts.

1. **Explore:** Students have concrete experiences with particles in the air. Students design and conduct an investigation measuring levels of air particles around the school and community.
2. **Concept Development:** Students identify and explain sources of natural and man-made air pollution.
3. **Application:** Students apply knowledge of sources of air pollution by predicting air quality in a *Mystery Town* game.

Evaluation should be conducted throughout all stages of the lesson to assess students' thinking during the activities and to uncover any misconceptions of the key concepts. Each day is further broken down following a 5E lesson format with modifications and differentiation strategies provided.

Lesson Plan Overview	
Measuring Air Pollution *Explore*	**What do you know about air pollution?** ● Gather prior knowledge on air pollution. ● Provide concrete experiences with particles in the air. ● Introduce natural and man-made sources of air pollution. ● Introduce health impacts of air pollution. **Measure air pollution at your school.** ● Introduce particulate matter in the air with size comparisons. ● Introduce air quality monitoring equipment. ● Design and conduct an investigation measuring levels of particles around the school. ● Conduct a smog in a jar demonstration to explore high levels of air pollution. ● Select locations to measure air quality around the local community.
Influencers of Air Pollution *Concept Development*	**What are sources of air pollution and their impact?** ● Analyze particle levels and related sources of air pollution around your community. ● Compare local air quality measures with regional and global readings. ● Identify factors across the world that contribute to high levels of air pollution. ● Predict and verify the effects of poor air quality on health.
Mystery Town *Application*	**Mystery Town: Apply knowledge of air pollution and sources.** ● Apply knowledge on sources of air pollution by predicting air quality. through identification of potential sources. ● Develop ideas to reduce sources of air pollution.

How to Use Air Pollution Unit

The lesson sequence provided is intended for a week-long lesson on air pollution. The following are the recommendations for adapting the content to your classroom:

1. Review the daily lesson plans to determine time and materials needed. Depending on the level of your students and classroom environment, determine a plan for implementation. Modifications are provided throughout.
2. Review the *Background Knowledge* section for important content information prior to implementing the lessons.
3. Review the links below to access additional content including:
    a. **Teacher Companion Slides:** These are intended to support areas of direct instruction.
    b. **Student Handouts:** These guide students through the activities.
    c. **Air Quality Google Form:** Students can submit their air quality data using this form to be entered in a national database.

Click the following links to support implementation of this lesson in your classroom. These will create a copy in your Google Drive.

Teacher Companion Slides

Student Handouts Part A
Students Handouts Part B

Air Quality Google Form

Important Note on Lesson Scope: *A focus on PM 2.5*
The EPA establishes an air quality index that consists of five major air pollutants regulated by the Clean Air Act. Each of these pollutants has a national air quality standard set by EPA to protect public health:

- ground-level ozone
- particle pollution (also known as particulate matter, including PM2.5 and PM10)
- carbon monoxide
- sulfur dioxide
- nitrogen dioxide

The focus of this lesson sequence is on particulate matter, more specifically PM 2.5 or particles smaller than 2.5 microns. Death rates from particulate matter pollution tend to be higher than that of ozone and are a key area of concern. Examples of this include dust, soot, dirt, plant spores, pollen, and smoke from wildfires. Another common source is incomplete combustion of gasoline in car engines, which is the largest contributors to smog.

Standards Alignment

Texas Essential Knowledge & Skills	
§112.16. Science, Grade 5	(9) Organisms and environments. The student knows that there are relationships, systems, and cycles within environments. The student is expected to: (C) Predict the effects of changes in ecosystems caused by living organisms, including humans, such as the overpopulation of grazers or the building of highways.
§112.19. Science, Grade 7	(D) Earth and space. Earth and space phenomena can be observed in a variety of settings. Both natural events and human activities can impact Earth systems. There are characteristics of Earth and relationships to objects in our solar system that allow life to exist.
§112.20. Science, Grade 8	(E) In addition, students explore how organisms and their populations respond to short- and long-term environmental changes, including those caused by human activities.
Next Generation Science Standards	
MS-ESS3-3 Earth and Human Activity	Apply scientific principles to design a method for monitoring and minimizing a human impact on the environment.
MS-ESS3-4 Earth and Human Activity	Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.
4-ESS3-1 Earth and Human Activity	Obtain and combine information to describe that energy and fuels are derived from natural resources and their uses affect the environment.
5-ESS3-1 Earth and Human Activity	Obtain and combine information about ways individual communities use science ideas to protect the Earth’s resources and environment.
C.3(B), B.3(B), E.3(B), I.3(B), P.3(B)	Communicate and apply scientific information extracted from various sources such as current events, published journal articles, and marketing materials.
C.3(E), E.3 (E), I.3(E), P.3(D)	Describe the connection between science and future careers.

Background Knowledge for Educators

Prior to implementing the *What's in our air?* lessons, educators are encouraged to review the following background information for the basics on sources of air pollution, measuring air quality, transportation emissions, and health impacts.

United States Environmental Protection Agency (EPA):

- Basics of Particulate Matter
- Health Impacts

AirNow: Measure Air Quality

World Health Organization (WHO):

Outdoor Air Quality Fact Sheet

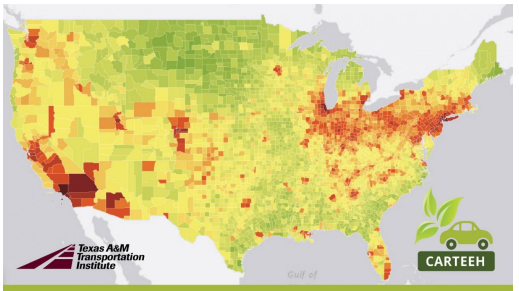
Our World In Data:

- Air Pollution Summary
- Outdoor Air Pollution

Additional Resources:

- Which US Cities Have the Best & Worst Air Quality?
- Vehicles and particulate matter
- Background on PM (read intro section)
- Air Pollution Kills as Many People as Cigarettes (WebMD)

CARTEEH Research Connection: Heat map shows relationship between traffic-related air pollution and childhood asthma. Click here for a news article.



TTI HEAT MAP SHOWS

Asthma cases attributable to traffic-related air pollution dramatically decreased between 2000 and 2010

Video Resources:

- Air Pollution 101 (National Geographic) 1:23
- Air Pollution | The Dr Binocs Show (Peekaboo Kidz) 6:09
- Air Pollution for Kids (Learn Bright) 7:04
- Why Air Quality In The U.S. Is So Bad (CNBC) 11:08
- Breathe Life - How air pollution impacts your body (WHO) 1:18
- How Is Air Pollution Affecting Your Health? | Ever Wondered (Spark) 21:18
- What is Air Pollution and How Does it Harm Us? (Concerning Reality) 8:00
- What does Air Pollution PM 2.5 do inside children's body and brain? (UNICEF) 2:53

CARTEEH Course Materials: CARTEEH has developed a unique, cross-disciplinary course titled "Traffic-Related Air Pollution: Emissions, Human Exposures, and Health." The course is intended to form the basis for a three-credit-hour graduate-level course, but teachers are encouraged to review the available lecture slides for background information, especially the introduction to air quality. Slides can accessed here.

Additional Resources and Activities

The following are recommended resources related to air pollution to supplement the activities in this unit.

Resource	Details	Link
Build Your Own Particle Sensor	Particulate matter (PM) sensor kit that can be built by students.	**EPA:** https://www.epa.gov/air-research/air-quality-and-energy-choice-stem-activities-educators
Generate: The Game of Energy Choices	*Generate* is an interactive game that allows students to explore energy choices and teaches the considerations and costs in deciding what type of energy generation to build.	**EPA:** https://www.epa.gov/climate-research/generate-game-energy-choices
AirNow Curriculum and Flag Program	Activity sheets (K-12), coloring pages, virtual flag display, live air quality data	**AirNow:** https://www.airnow.gov/education/
Air Pollution & Air Quality	Students investigate air pollution through activities on visible and invisible air pollutants, and gain an understanding of how engineers develop and use technology to reduce and clean-up air pollution in our atmosphere. (Grade 5)	**TeachEngineering** https://www.teachengineering.org/curricularunits/view/cub_air_pollution_unit

Measuring Air Pollution

Exploration

Teacher: _____ **Date:** _____

Subject: Science/Earth Science **Grade**: 5-8th

Estimated time: 45 - 60 minutes

Lesson Plan Overview	
Description	**What do you know about air pollution?** ● Gather prior knowledge on air pollution. ● Provide concrete experiences with particles in the air. ● Introduce natural and man-made sources of air pollution. ● Introduce health impacts of air pollution. **Measure air pollution at your school** ● Introduce particulate matter in the air with size comparisons. ● Introduce air quality monitoring equipment. ● Measure levels of particles around the school. ● Conduct Smog in a Jar to explore high levels of air pollution. ● Analyze levels of particulate matter around the school. ● Select locations to measure air quality around the local community.
Materials	❑ Whiteboard ❑ Flashlight/projector ❑ Clean and dirty household air filters ❑ *Optional:* Magnifying glasses ❑ Air quality monitor: See next page ❑ Computer access to upload data to Air Quality Google Form ❑ Large glass jar with lid (example) ❑ Paper scraps and matches or a lighter ❑ *Optional:* Foam pool noodle and golf ball
Lesson Objectives	*In this lesson, students will,* 1. Recognize that air contains many different particles that are very small and difficult to see without tools such as an air filter. 2. Identify a key distinction between particles: natural and man-made. 3. Describe potential impacts of air pollution. 4. Differentiate particles by size. 5. Practice taking scientific measurements of air quality. 6. Identify patterns in air pollution by analyzing location contexts to determine that air quality is affected by the factors of a location.
Differentiation Strategies	● Open-ended, multiple response questions and appropriate wait time allow for many students to share thoughts. ● Think-Pair-Share used prior to class discussions will foster confidence in shared ideas. ● Conclude the day with the individual or paired summary task. This allows all students to identify and leave with the key concepts from the day's lesson. ● Allow for shared responsibility by dividing students into groups with multiple strengths, including recording data and identifying locations.

Selecting an Air Quality Monitor

Sensors measure particle level (PM 2.5) and can range in price from $80 to over $300. CARTEEH has school grants to support the purchase of an air quality monitor. Click here to request a grant!

Recommendations for Air Quality Monitor

Click here for a guide on how to choose a monitor.

Air Quality Monitor Options	
$50 - $100	**AtmoTube PLUS** https://atmotube.com/products/atmotube-plus?view=en **Langkou Air Monitor:** https://www.amazon.com/Detector-Pollution-Temperature-Humidity-Professional/dp/B08Q7YMX9X/ref=pd_ybh_a_3?_encoding=UTF8&psc=1&refRID=5049QRV6BTNP1VJBP4W2 **Temtop M10 Air Quality Monitor:** https://www.amazon.com/dp/B07DHXQXGK/?tag=best-air-quality-monitor-20&asc_source=browser&asc_refurl=https://www.bobvila.com/articles/best-air-quality-monitor
$100 - $200	**EG Air Monitor** https://www.amazon.com/Air-Pollution-Formaldehyde-Detector-Temperature/dp/B078ZS8RVL/ref=pd_ybh_a_1?_encoding=UTF8&psc=1&refRID=5049QRV6BTNP1VJBP4W2
$200 - 300	**AirVisual Pro** https://www.iqair.com/us/air-quality-monitors/airvisual-series **PurpleAir** https://www2.purpleair.com/collections/air-quality-sensors/products/purpleair-pa-ii

Videos on air quality monitors:

- Atmotube PRO: PM sensor: https://www.youtube.com/watch?v=nljyH-YGnPI
- IQ Air: https://www.youtube.com/watch?v=b90gSYGHiKU

I. ENGAGE

Gather prior knowledge and provide concrete experiences with particles in the air

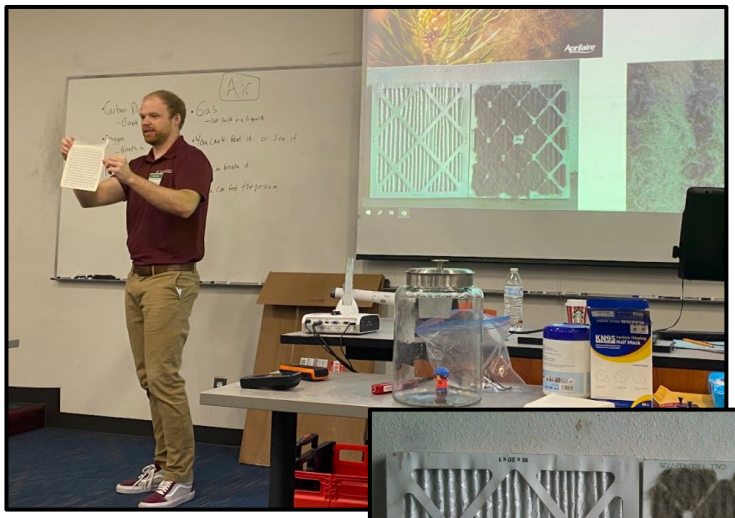
1. Start the lesson by drawing out prior knowledge of air pollution by asking the class: ***What are some things that are in our air?*** **Record** all student responses on the board exactly as stated by the students to emphasize the value of their ideas. Use wait time to draw out an exhaustive list. Ask follow-up questions that pull from students' prior experiences. For example, *What happens to some people (including some of you) when you go outside on a spring day? What are some things you might observe about the air during a very windy day?* Example responses: oxygen, dust, dirt, pollen.

2. After getting a list, **ask:** ***How might we prove there is different stuff in the air?*** After collecting ideas, guide students towards the idea of dust and dirt traveling in the air with questions such as: *What happens if you don't clean a surface for a long time? Where is the dust coming from?*

3. Provide students with some **concrete experiences** of "stuff" in the air:

    a. **Projector:** Turn on a flashlight or a projector and then turn off classroom lights to show particles traveling in the air. ***What is all this stuff traveling in the air?***

    b. **Air Filter:** ***How do people keep the air in their homes and schools clean from all these particles?*** Show students an air filter that is full of dust and one that is clean. Have students compare the two. If possible, break students into groups to investigate both clean and dirty filters using magnifying glasses. After exploring both filters, have students brainstorm a list in response to the question: ***What sources could this dust and the other stuff have come from?***



I. ENGAGE – *continued*

Introduce natural and man-made sources of air pollution

4. After these experiences, the goal is now to **identify the variety of sources that put "stuff" into the air**. **Create two columns on the board**, one representing man-made sources and the other natural sources; however, do not reveal the column headers.

5. **Ask**: ***How does air become dirty?*** As students suggest ideas, place them in the appropriate column. Guiding questions may need to be used such as pointing to seasonal events in California, knowledge about Houston/Los Angeles and other major cities, or prior experiences such as riding on a school bus or driving on the highway. The table below is a possible list you might create as a class. Note that not all of these will be shared by students as the goal is to generate a list of the students' prior conceptions about air pollution. This list will be valuable as the lessons progress so leave it visible. Refer to and modify as new ideas are uncovered.

6. When students have exhausted ideas about the sources of air pollution, ask them to **Think-Pair-Share** with their neighbor about the reason(s) there are two columns. ***What can you infer about the two columns? What are the similarities and differences? What title would you give each column?*** Guide students to identify that the two columns represent the categories of air pollution: man-made and natural.

Man-Made	Natural
Cars and other vehicles	Wildfires
Other transportation (e.g., airplanes)	Volcanoes
Construction site dust	Wind blowing dust or sand
Farmers burning fields	Animals
Power plants	Pollen from plants

This table is an example of student responses for ways the air becomes dirty. The column headings are not revealed until the end of the discussion.

Introduce health impacts of air pollution

7. **Ask:** ***Why should we care about dirty air?*** Some ideas that students generate about problems are sickness, asthma, and unhealthy trees. Show students a video, such as Air Pollution 101 featuring some of the dangers of air pollution. The Nasco dual inflation lungs is an excellent demonstration of human impacts.

II. EXPLORE

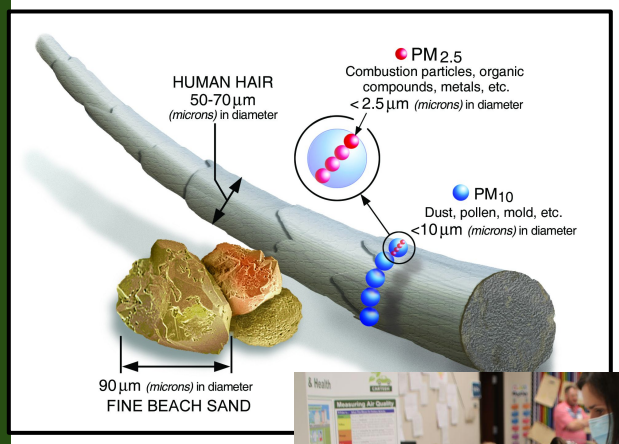
Introduce particulate matter in the air with size comparisons

1. Now that students may recognize the importance of measuring levels of air pollution, **ask**: ***How might we measure just how dirty a particular location of air is?*** Bring back out the dirty and clean air filters. *How could we accurately compare the air in two different locations?*

2. One idea that students might suggest as a way of determining room air quality is to "count the stuff" on the air filters and compare them. Referring to this idea, introduce the concept of **particle size** by having students examine a single strand of hair from their heads. Point out that hair is still visible to the human eye and ask them to predict, *How much smaller might a single piece of dust from the filter be or smoke from a car?*

3. Reveal the scientific names and sizes of the various types of particles as described below. The EPA recommends using the props of a pool noodle as a piece of hair, a golf ball for dust and pollen, and a grain of sand for combustion particles. Do not worry about the units. The important takeaway for students is the size scale of these particles.
   - Hair (~ 50 microns): pool noodle
   - Dust and pollen (~ 10 microns): golf ball
   - Combustion particles like exhaust from a car (~ 2.5 microns): grain of sand

4. **Health Impacts: Ask, *Why might smaller particles be more harmful to humans?*** Particles smaller than 10 microns are the most dangerous as they can get deep into your lungs and some may even reach your bloodstream. Exposure to fine particles can cause short-term health effects such as eye, nose, throat and lung irritation, coughing, sneezing, runny nose and shortness of breath. Long-term effects include decreased lung function, heart attacks, and cancer. Refer back to the lung demonstration or a video demonstration.



Air Pollution Compared to Smoking: The focus is often on the impacts of smoking, but the World Health Organization estimates that the number of deaths caused by air pollution is about equivalent to tobacco-related deaths, 7 million each year. Click here to share an article with your students. However, this risk depends on your location and proximity to bad air quality. Looking at the scale on the next page, inhaling air at 22 PM 2.5 (moderate) for 24 hours equals 1 cigarette per day. An average smoker smokes about 14 cigarettes each day, equivalent to 308 on our scale (hazardous). Such air pollution is uncommon and often resulting from events like wildfires.

II. EXPLORE - *continued*

Introduce air quality monitoring equipment

5. Now that students are hopefully convinced they should care about air pollution, **ask,** *Considering the size of particles, what type of tool would we need in order to accurately measure the amount of "stuff" in the air?*

6. **Show** students the air quality monitoring devices. These monitors measure particulate around 2.5 microns. Depending on the developmental level of students, avoid units as it may add confusion. Instead, direct attention to the idea that the air quality monitor number will increase with more particles in the air. Show the reading for the classroom and ask students, ***How could we change the monitor's reading (for example opening doors or windows)?***

7. Connect the monitor's reading with the standardized scale used by scientists (click here for more details and see image to the right). Highlight the checkpoints, particularly 35.5, which indicates air that is considered unhealthy for humans. Introduce the term **air pollution,** which can be defined as too many particles in the air that become hazardous to our health.

$PM_{2.5}$	Air Quality Index
0 to 12.0	Good 0 to 50
12.1 to 35.4	Moderate 51 to 100
35.5 to 55.4	Unhealthy for Sensitive Groups 101 to 150
55.5 to 150.4	Unhealthy 151 to 200
150.5 to 250.4	Very Unhealthy 201 to 300
250.5 to 500.4	Hazardous 301 to 500

Measure levels of particles around the school

8. Next explore 2.5 PM readings at various locations around the school. **Challenge st to develop a class procedure for collecting air pollution data.** Possible questions *Think back to our list of sources of air pollution. How might we capture these sour outside? What data might be important to collect if we are trying to determine th factors that lead to increased pollution? How could we go about collecting and organizing data?*

9. The table below is an example of a data organizer that will assist students in collecting and managing data. With the class, prepare a list of reasonable places to capture data (e.g., classroom, playground, parking lot, etc.). Depending on the number of monitors, this activity can be conducted in small groups or as a class. Additionally, make sure that students are prepared with hallway and outdoor procedures.

Location	PM 2.5	Observations
Classroom	3	Windows and door closed, springtime
Cafeteria	7	No people, large space
Playground	6	Lots of trees and plants, windy
Parking Lot	6	Windy, no cars running, fewer plants
Exhaust behind a car	52	Placed directly behind tailpipe, an older truck, see and smell smoke
Street	8	6 cars drove by, windy

II: EXPLORE - *continued*

10. The readings from around the school may not vary much (except the car exhaust reading if collected). The key concept is to demonstrate that particle levels can differ in different areas. Before heading inside, provide students a concrete experience of high levels of particle pollution by conducting the **Smoke in a Jar demonstration.** This demonstration results in very high particle readings (often the limits of the monitor).

Smoke in a Jar Demonstration

Items required: paper, lighter, large jar with lid (small figurine is optional).

1. Ask, *What will happen when I light this paper, place it inside the jar, and close the lid?*
2. Light the paper on fire and carefully place it inside the jar. Let the paper burn for a few seconds and then close the jar. The jar will start to fill with smoke.
3. Ask students to make observations and then ask, *How might the particle level compare to the data we collected so far? What evidence do you have to support your reasoning?*
4. Open the jar and quickly take a measurement. The monitor will indicate an extremely high PM 2.5 reading of 600–999 (max). *Where does this fall on our air quality scale? How does this compare to the other readings we have found? Why might this reading be different?*

11. While students are looking at the smoke in the jar ask, ***Where might this high concentration of air pollution exist in the natural world?*** Answers might include a wildfire or house fire. *Consider a firefighter, what kind of equipment would they need to stay safe in a fire?* Connect this scenario back to health impacts. *What do you think someone in this environment is experiencing? How might this impact their health?*

III. EXPLAIN

Analyze levels of particulate matter around the school

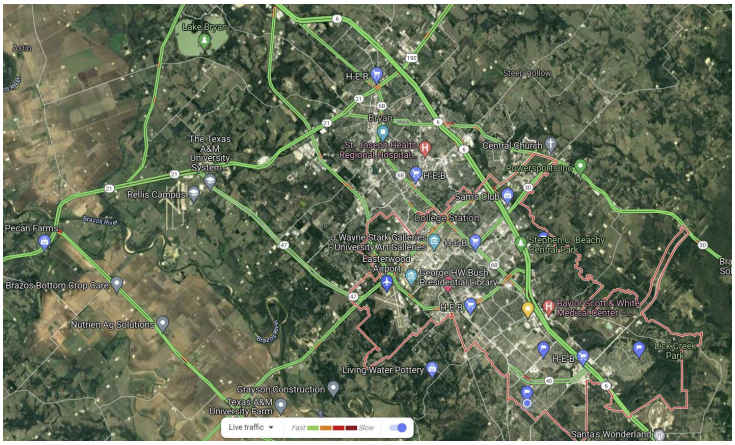
Move back inside to **analyze and reflect** on the collected data. Challenge students to organize the observations and data into an easily readable visualization (e.g., bar graph, t-chart, etc.). Discuss as a class or in small groups the contexts and scenarios that lead to higher or lower air quality readings. Refer back to the class-generated list of air pollution sources. Example questions include: ***How is the air quality around our school?*** *What common elements do you notice in locations with higher readings? Based on your observations, what things might be causing different levels of particles (if any differences are observed)?*

IV. ELABORATE

Select locations to measure around the local community

1. **Ask:** ***How do you think the particle levels might change around our community?*** The goal is to now extend this investigation to sources in your local town or city. Ideally, provide students with a map or access to Google Maps. Provide groups time to brainstorm a list of places in the community that they expect would have 1) high, 2) medium, and 3) low particulate matter. Direct students to be creative, specific, and to include justification. For example, if a student suggested a traffic intersection, ask *How would you determine if this was a high traffic area? or How might the time of day impact the level of air pollution?* **Research extension:** An optional extension would be to provide computer access and have students research the community for information on local industries, traffic patterns, green spaces, and other potential high air pollution locations.

2. After researching, bring the class together and share ideas for local areas of high and low air pollution. Pick 5–8 of the locations presented, targeting sites with predicted high, medium, and low levels of pollution.



IV. ELABORATE - *continued*

3. After establishing a class list, **design an investigation** to measure patterns of particulate matter in the local community with the goal of identifying sources of air pollution. **Ask**: *Based on our previous experience around the school, what data should we collect? How can we organize this data?*

4. Either as a class or in groups, have students **rank the final list of locations** (high to low levels of particulate matter) and discuss the reasons for each ranking. Make sure the rationales are based on the observations and evidence from the previous lab and students' prior experiences with air pollution. Save the finalized list, rankings, and justifications.

Data Collection: The teacher will most likely have to conduct the data collection around the community. Consider taking a picture or a video while collecting data to share with students. Some air quality monitors connect to WiFi, so students can follow live recordings from a computer.

Record the PM 2.5 reading and area observations. If you have access to multiple air quality meters, consider tasking students with the collection of some locations. Trust your judgment on sending meters home with students. Below is an example of data from around town. Students may add additional columns to the recorded data such as time of day, smells observed, weather, etc.

Location	PM 2.5	Observations
Drive-thru at McDonald's	26	Idling cars. No wind. 6 pm.
Mall parking lot	8	Many parked cars. Windy day. 3 pm.
Cow farm outside of town	16	Bad smell in the air. Very few cars driving by. 12 pm. No wind.
Gas station parking lot	18	The smell of gas. Several cars. Next to highway. 11 am.
Downtown park	6	Many trees. No cars nearby. Little wind. 10 am.

V. EVALUATE

1. To end this lesson, ask students to **reflect** on: *What are some situations or places where air pollution is strictly enforced?* Discuss the no-smoking policies in public places. Then, with a partner or solo, challenge them to write a response to this prompt: *Knowing what you've learned about air pollution and particle size, why is it important to have no-smoking policies in public spaces such as restaurants?*

2. **Optional extension:** Building on the ideas that air pollution *can* cause health and environmental impacts, and laws exist that serve to protect people (such as anti-smoking policies), have each student read the following article and write a brief response (paragraph or less) to this prompt: *Within our community, how might air pollution disproportionately impact people? That is, in what ways might the place someone lives, works, or goes to school cause a higher risk of being impacted by air pollution?* Depending on the ability of your class, you may wish to read and discuss the article together. Find a text-only version (for printing and sharing) on the next page.

Urban pollution can pose unseen risks to kids' immunity and more

Some pollutants appear to even raise kids' blood pressure

Science News for Students
By Esther Landhuis, 2021

Tobacco and other pollutants don't just stink up the air. They also alter immune cells in ways that could hurt the body. Some can raise blood pressure, even in kids. That's the finding of three new studies. Taken together, they show that dirty air does not just pose risks to the lungs. It also threatens the heart and the body's ability to fight infection.

One study analyzed 221 young kids living in Fresno. This central California city ranks among the nation's most polluted. In the American Lung Association's annual State of the Air report, "they get F's all the time," says Mary Prunicki. She's an immunologist at Stanford University, also in California. Her team wanted to see how that pollution affects child health. So, they collected blood and took blood-pressure readings from Fresno kids. Each was six to eight years old. The researchers also collected data from stations that monitor air pollution. This helped them figure out how much pollution each child had likely been breathing.

Among kids exposed to higher pollution levels, DNA in their immune cells showed chemical changes. The changes reflect the addition of a chemical group (a carbon atom attached to three hydrogen atoms). Once in place, these chemical groups act like genetic switches. They're called epigenetic, for "above" the gene. That's because they influence how genes work without altering their DNA. Epigenetic changes can later be inherited. Prunicki's group found epigenetic changes in four genes that regulate immunity. In fact, the blood in these children also contained fewer white blood cells. And that's a bad sign. The body produces those white cells to help fight infection and to rid itself of foreign substances.

What's more, the blood pressure in kids who had inhaled more air pollutants was higher. This suggests their arteries were getting stiffer. That can force your heart to work harder to pump blood. And that puts people at greater risk for heart failure.

Evidence of fire-linked changes

Wildfires spew some of the same chemicals, such as ozone and carbon monoxide, that pollute many urban cities. A second new study analyzed blood from people affected by the November 2018 Camp Fire. This was the deadliest wildfire in California history.

This study focused on a specific type of white blood cell. Part of the immune system's first responders, they are known as innate immune cells. The researchers looked at a group of these cells in bone marrow. They also looked at dendritic cells, which move relentlessly through the lining of the gut. When they find a foreign invader, they spew chemical messengers. These molecules tell the immune system "Something bad is going on," explains Angela Haczku. She's a physician-scientist at the University of California, Davis. Her team found that during the wildfire season, the immune cells showed molecular changes typical of inflammation or an allergic reaction. One of her graduate students, Melissa Teuber, reported their findings February 27 at the annual meeting of the American Academy of Allergy, Asthma & Immunology. (It was held virtually this year.) The immune changes persisted at least two months. They returned to normal within the next two to four months.

Related effects of cigarette smoke

Some immune cells in the Fresno kids reacted to certain pollutants right away. Other cells took weeks or months to show changes. It's unclear if some of these changes might last into adulthood. Scientists also don't know if moving into an area with clean air would reset the body's immune system back to normal. Scientists do know that prolonged exposure to urban air pollution makes people more prone to asthma and allergic disease. It also can shorten lifespan. Cigarette smoking is another source of air pollution. And a third study probed links between it and blood pressure in kids.

The researchers analyzed data from 8,520 U.S. kids who took part in a nationwide health survey. Some were as young as eight. Others were older, up to age 19. The study had measured blood levels of cotinine (KOH-tih-neen). It's a breakdown product of the nicotine found in tobacco. The researchers also noted whether the kids had smoked, lived with a smoker or had high blood pressure. Young smokers were more likely to have high blood pressure were than kids exposed solely to secondhand smoke. But all kids with cotinine residues were at elevated risk of having high blood pressure, says Rebecca Levy. She's a kidney doctor at Montefiore Medical Center in New York City and led the study. This was true whether the kids actually smoked or had just been around smokers.

"The more nicotine you had in your body, the more likely you were to have high blood pressure," she reports. And high blood pressure increases risk for strokes, heart disease and kidney problems. Her team published its findings February 23 in *JAMA Network Open*. In the future Levy hopes to get similar data on vaping. Among kids, "vaping is getting more popular," she notes. And some e-cigarettes have a "much higher nicotine dose than traditional cigarettes."

Identifying Sources of Air Pollution

Concept Development

Teacher: _____ **Date:** _____

Subject: Science/Earth Science **Grade**: 5 - 8th

Estimated time: 45 - 60 minutes

Lesson Plan Overview	
Description	**What are sources of air pollution and their impact?** ● Analyze particle levels and related sources of air pollution around the community. ● Compare local air quality measures with regional and global readings. ● Identify factors across the world that contribute to high levels of air pollution. ● Direct instruction on sources of air pollution and impacts. ● Investigate a town to determine air quality, sources, and impacts.
Materials	❏ Small whiteboards and markers for small group whiteboarding. ❏ *Optional:* Computers for each group ❏ Projector ❏ Computer lab access: https://www.iqair.com/us/ ❏ World's Most Polluted Cities: https://www.iqair.com/us/world-most-polluted-cities
Lesson Objectives	*In this lesson, students will* 1. Students will identify common features and scenarios that could influence higher and lower air quality readings. 2. Students will compare local air quality measures with regional and global readings. 3. Students will identify factors across the world that contribute to high levels of air pollution. 4. Students will predict and verify the effects of poor air quality on different communities.
Differentiation Strategies	● Requiring students to record the initial discussion of common features on their small group whiteboards will encourage cooperation and inclusion. ● Each student will have different locations to present as potential places to gather community data. Encourage that every student offer at least one location to investigate. ● Investigate the health risks of air pollution through multiple forms, including reading and a short writing exercise. ● A shared task with independent research encourages each student to contribute to the group in a meaningful way. ● Visual maps of global air pollution data are helpful in spotting air quality trends.

I. ENGAGE

Analyze particle levels and related sources of air pollution around the community

1. **Show** students this video of a CARTEEH researcher working on air quality: https://youtu.be/jIdBGFHcJnw. Ask questions such as, *How is Jeremy's work similar to what we are doing in our investigation? What do you think is the purpose of the climate-controlled facilities in the video?*

2. **Review** the list of community locations from the previous day and have a student refresh the class on *why* they ranked certain places higher or lower in predicted particle pollution.

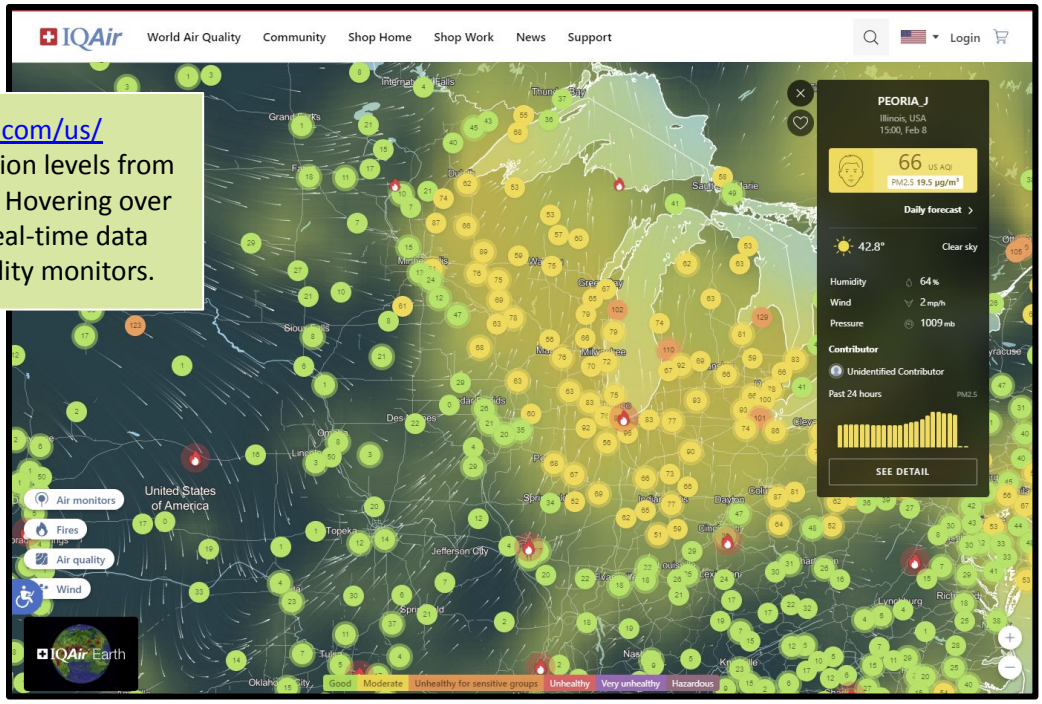
3. Reveal particle levels measured at each location. Have students partner up and engage in a **Think-Pair-Share** about the patterns of the newly collected data in relation to the school data and what they have learned about air pollution so far. Possible questions to ask: *What do you notice about the particle pollution levels at each location? How does this new data compare to the predictions we made? What factors might explain the differences in data? What patterns do you notice across all the data and observations collected?* The objective is to confirm that around the school and community, there are things that create a large amount of particulate matter, and the sources are often man-made or have a tie to human activities.

II. EXPLORE

Compare local air quality measures with regional and global readings

1. The next step is to move from local to **global patterns of air pollution**. Explore global air pollution data by projecting the global map found here: https://www.iqair.com/us/. Begin by showing the statewide data and ask the class to interpret the data. Then, referring back to the class list of sources of air pollution, ask for suggestions of cities or locations around the world that they would expect to have elevated levels of pollution.

https://www.iqair.com/us/ provides air pollution levels from around the world. Hovering over a site will reveal real-time data using local air quality monitors.



II. EXPLORE - *continued*

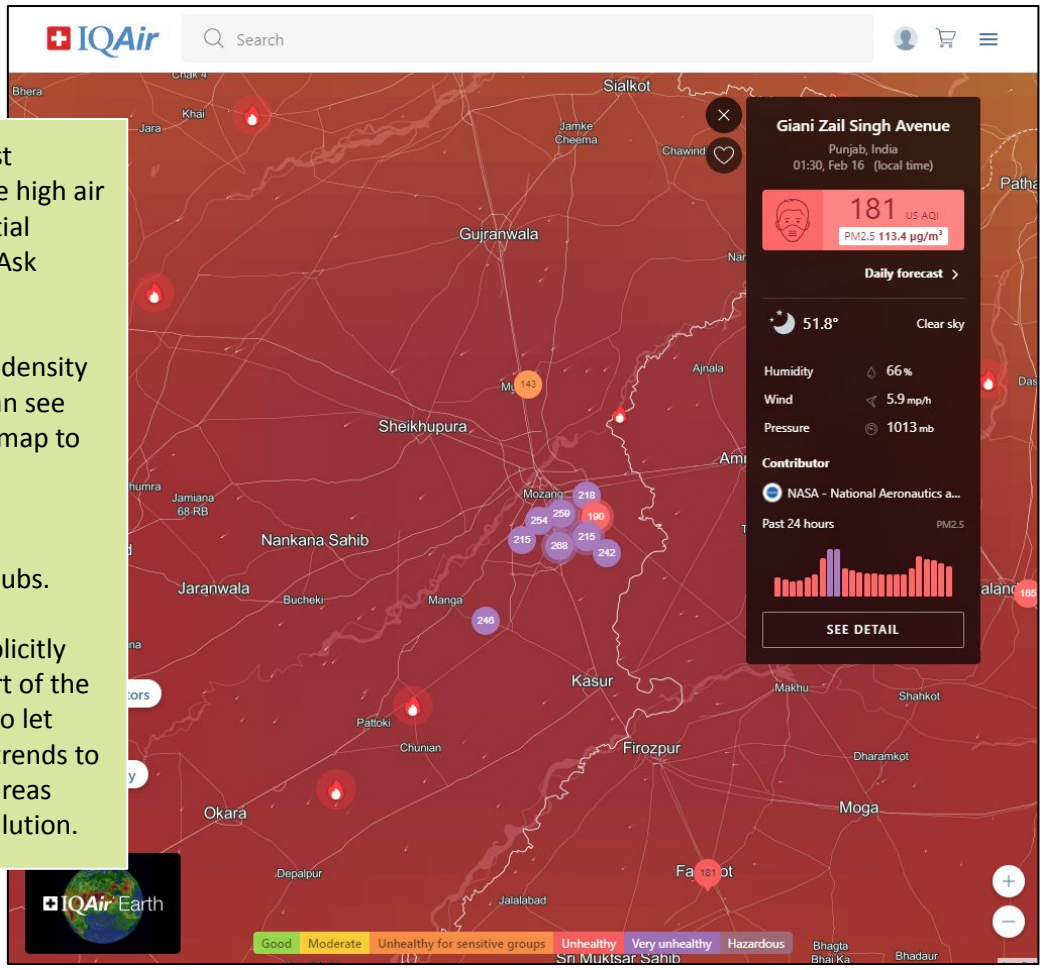
Identify factors across the world that contribute to high levels of air pollution

2. Use questions to help students make connections between potential man-made and natural sources (e.g., wildfires, factories, crop burning) as well as other critical factors (e.g., population density, weather, policies impacting air quality, geography). Spend time exploring several notable cities with poor air quality such as Los Angeles, New York City, Paris, Beijing, New Delhi, Tlaxcala (Mexico). You can use the current world air quality ranking: https://www.iqair.com/us/world-air-quality-ranking. Additionally, spend time looking at places with good air quality such as Northern Europe, Northwest Canada, and the eastern Australian coast. With each location (along with any that students might be interested in), have students make predictions and explanations about the causes of the reading. Places with higher industry, populations, vehicles, and natural particulate sources such as wildfires will have a higher air quality measure than places with lower population densities and more vegetation. Clicking on larger cities will provide detailed historical information and a discussion of sources of air pollution. For example: https://www.iqair.com/us/india/delhi

Allow students to suggest locations that might have high air pollution. Discuss potential sources of air pollution. Ask students to think about contributors such as:

- High population density
- Wildfires (you can see wildfires on the map to the right)
- Industry
- Shipping ports
- Transportation hubs.

Sources will be more explicitly discussed in the next part of the lesson. The goal here is to let students explore global trends to start seeing patterns in areas with high and low air pollution.



III. EXPLAIN

Direct instruction on sources of air pollution and impacts

Students may have a general idea about why some places have drastically lower air quality than other places, but the objective is to establish some key factors that increase air pollution. Specifically, students should recognize that human activities such as factories, power plants, vehicles, and dense urban living contribute to increasing air pollution. Additionally, natural factors such as recent wildfires and daily weather, geographical barriers like mountains, and government environmental policies can alter a location's air quality. Direct instruction of the natural and man-made factors which influence air pollution as well as a review of the major ideas (particulate matter size, sources of air pollution, health risks, etc.) may be beneficial to implement now. Refer back to air quality data map to illustrate the impact of proximity to sources of air pollution.

IV. ELABORATE

Investigate a town to determine air quality, sources, and impacts

Students will work in small groups to complete the **Contextualizing Air Pollution** assignment. See the included document for a template assignment sheet.

1. Sort students into groups of 2–4 and assign each group a community from the following list:

Los Angeles, U.S. Sydney, Australia Houston, U.S. Delhi, India Paris, France	Stockholm, Sweden Kanpur, India Boise, U.S. Beijing, China Lahore, Pakistan	Kabul, Afghanistan Hotan, China Honolulu, U.S. Madrid, Spain Vancouver, Canada

2. Task each group with generating a brief report on their community's air quality. Information to research might include:
    - Air quality reports (average and that day)
    - Population and population density
    - Average weather
    - Geographic information
    - Environmental policies specifically regarding air quality and pollution
    - Other relevant information such as major industry and local environmental problems

3. Instruct students to start their investigation using https://www.iqair.com/us and then supplement with researching local news, environmental organizations, weather reports, and geographic maps to create a brief but thorough report on the air quality of their assigned community.

V. EVALUATE

Leave time for groups to briefly share their assigned community's air quality and associated factors at the end of class. Alternatively, groups can prepare a brief presentation of their community and related air pollution factors. If there is time, have students complete the post-presentation question and submit their Contextualizing Air Pollution assignment sheet for a grade.

Mystery Town
Application

Teacher: _____ **Date:** _____

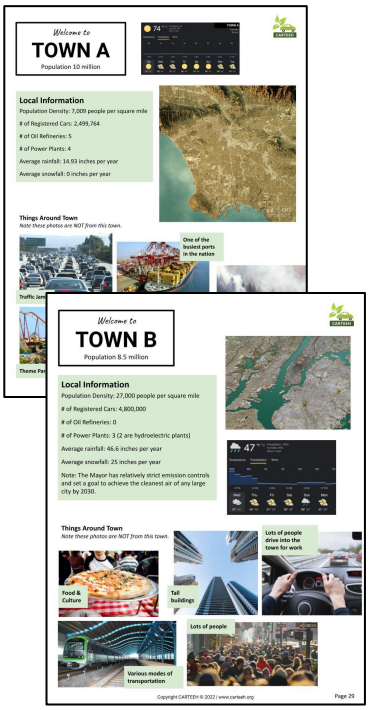
Subject: Science/Earth Science **Grade**: 5 - 8th

Estimated time: 40 - 50 minutes

Lesson Plan Overview	
Description	**Mystery Town: Apply knowledge of air pollution and sources** ● Apply knowledge on sources of air pollution by predicting air quality through identification of potential sources. ● Develop ideas to reduce sources of air pollution.
Materials	❑ Mystery Town printed materials
Lesson Objectives	*In this lesson, students will* 1. Students will apply knowledge of sources of air pollution and contributing factors to lower air quality to a novel situation. 2. Students will predict the air quality of a town by identifying known characteristics and contexts. 3. Students will develop solutions for reducing sources of air pollution.
Differentiation Strategies	● Instead of using all six towns, assign each group a town to investigate and determine the main sources of air pollution. ● Students work in groups to compare two towns for differing sources of air pollution. ● Groups present on their justification for each air quality level based on the data provided. ● Students sort the towns and rank group into categories of low, medium, and high air pollution.

I. ENGAGE

Show students this video about air pollution in the United States: https://www.youtube.com/watch?v=3_IoGGijsu4



II. EXPLORE

Apply knowledge on sources of air pollution

Complete the **Mystery Town** activity found using provided handouts. Students will be provided with 6 locations in the United States. Students will determine the sources of air pollution and other contributing factors through an investigation of provided city demographics, maps, and weather charts. While students are working, listen to conversations and ask guiding questions such as *How were the towns similar/different?*, *What evidence do you have for this source?*, *Why might one source of pollution be more significant than another in a particular town?*. Students will complete the provided chart, and they can attempt to guess the location of the Mystery Town based on clues provided (this part is just for fun!)

III. EXPLAIN

As a class, discuss the sources of air pollution that were identified. Reveal Mystery Town levels and sources of air pollution. *Did these match your predictions? What are the sources of air pollution? What is surprising? What are the health impacts?* Find the mystery towns on https://www.iqair.com/us/. What is the real-time measurement at that location?

IV. ELABORATE

Develop ideas to reduce air pollution

Now that sources of air pollution are identified, ask students to consider personal actions they can take to improve the quality of air. If students live in a place with good air quality, consider selecting one of the Mystery Town locations or another location with high PM 2.5 levels. Students will propose an idea such as an action they or other residents can take or a rule for the community that will improve the air quality. Ideas should be justified with ideas developed in this unit. For example: “One action I can do to help air pollution is to turn off the lights when I leave the room. Lights use electricity which comes from power plants. Power plants make lots of pollution. If I use less electricity, there will be less pollution made!”

V. EVALUATE

Provide students with a summative assessment (example provided) to determine knowledge of sources of air pollution.