Unit 7: Atmospheric Pollution
UNIT PLAN

AP Environmental Science
Unit 7
Suggested Duration: 12 Days

TABLE OF CONTENTS

UNIT NARRATIVE

This unit begins by introducing students to air pollution with a webquest that explores the pollutants regulated by the Clean Air Act (day 01). The webquest is designed to help students build context around the Three C's (Causes, Chemicals, and Consequences) and potential solutions for the 6 Criteria air pollutants (days 01-02). The webquest also includes opportunities to practice data analysis of graphs of the Criteria Pollutants over time and to make connections between air pollution and their lives by exploring air pollution in their city/region. Next students will complete an online module from High Adventure Science to explore more about air pollutants by categorizing them as visible or non-visible (day 03).

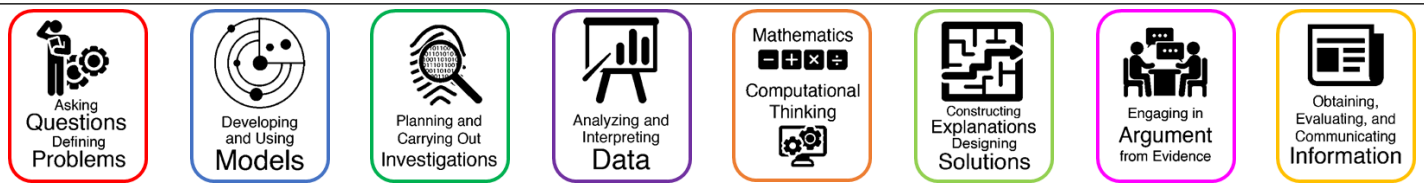
Next students will be introduced to Secondary Pollutants by completing a High Adventure Science module (day 04) to explore how Primary air pollutants undergo chemical reaction in the atmosphere to create Secondary Pollutants. Now students are ready to explore Photochemical Smog, the first of the two Secondary Air Pollutants covered in this unit, using a case study that provides opportunities for student to practice with FRQ style questions and helps students make connections between Photochemical Smog and Thermal Inversions (day 05). Then students will explore Acid Rain over a three day lesson arc (days 06-08) . First students will complete the pre-lab questions, set up the experiment, and take initial measurements before waiting 48 hours to complete the lab (day 06). While waiting for the Acid Rain Lab to be ready for final measurements the teacher will facilitate two demonstrations, measuring the pH of "normal" rain and acid rain by creating simulated regular rain and acid rain in the lab, and students will explore a reading and videos further explaining the Three C's for acid rain (day 07). Finally, students will complete the lab by taking final measurements and answering analysis questions (day 08).

The next lesson pivots to explore some of the ways air pollutants can be reduced at their sources to prevent it from being released into the atmosphere as well as with conversation, regulation and alternative energy resources (day 09). This unit concludes with a lesson exploring the often-overlooked air pollution that people are exposed to indoors. Students will work in small groups to complete a station rotation activity to access information from the EPA to describe the Three C's about the most common indoor air pollutants in the table on the student handout (day 10).

*NOTE – Teachers will need to create a free account with High Adventure Science in order to facilitate online lessons during this unit. Click the REGISTER button at the top right of this page - **High Adventure Science**.*

Focus on Disciplinary Literacy

In science, disciplinary literacy is synonymous with the science and engineering practices. The SEPs are the context through which all science concepts should be taught. In the lessons, you will find the Science and Engineering practices icons when the SEPs are being explicitly used by students.



UNPACKED CONTENT STANDARDS

Below are the standards **taught** and **assessed** in this unit.

Topic		Learning Objective		Essential Knowledge	
7.1	Introduction to Air Pollution	STB-2.A	Identify the sources and effects of air pollutants.	STB-2.A.1	Coal combustion releases air pollutants including carbon dioxide, sulfur dioxide, toxic metals, and particulates.
				STB-2.A.2	The combustion of fossil fuels releases nitrogen oxides into the atmosphere. They lead to the production of ozone, formation of photochemical smog, and convert to nitric acid in the atmosphere, causing acid rain. Other pollutants produced by fossil fuel combustion include carbon monoxide, hydrocarbons, and particulate matter.
				STB-2.A.3	Air quality can be affected through the release of sulfur dioxide during the burning of fossil fuels, mainly diesel fuels.
				STB-2.A.4	Through the Clean Air Act, the Environmental Protection Agency (EPA) regulated the use of lead, particularly in fuels, which dramatically decreased the amount of lead in the atmosphere.
				STB-2.A.5	Air pollutants can be primary or secondary pollutants.
7.2	Photochemical Smog	STB-2.B	Explain the causes and effects of photochemical smog and methods to reduce it.	STB-2.B.1	Photochemical smog is formed when nitrogen oxides and volatile organic hydrocarbons react with heat and sunlight to produce a variety of pollutants.
				STB-2.B.2	Many environmental factors affect the formation of photochemical smog.
				STB-2.B.3	Nitrogen oxide is produced early in the day. Ozone concentrations peak in the afternoon and are higher in the summer because ozone is produced by chemical reactions between oxygen and sunlight.
				STB-2.B.4	Volatile Organic Compounds (VOCs), such as formaldehyde and gasoline, evaporate or sublimate at room temperature. Trees are a natural source of VOCs.
				STB-2.B.5	Photochemical smog often forms in urban areas because of the large number of motor vehicles there.
				STB-2.B.6	Photochemical smog can be reduced through the reduction of nitrogen oxide and VOCs.
				STB-2.B.7	Photochemical smog can harm human health in several ways, including causing respiratory problems and eye irritation.
7.3	Thermal Inversion	STB-2.C	Describe thermal inversion and its relationship with pollution.	STB-2.C.1	During a thermal inversion, the normal temperature gradient in the atmosphere is altered as the air temperature at the Earth's surface is cooler than the air at higher altitudes.
				STB-2.C.2	Thermal inversion traps pollution close to the ground, especially smog and particulates.
7.4	Atmospheric CO2 and Particulates	STB-2.D	Describe natural sources of CO2 and particulates.	STB-2.D.1	CO2 appears naturally in the atmosphere from sources such as respiration, decomposition, and volcanic eruptions.
				STB-2.D.2	There are a variety of natural sources of particulate matter.
7.5				STB-2.E.1	Carbon monoxide is an indoor air pollutant that is classified as an asphyxiant.

	Indoor Air Pollutants	STB-2.E	Identify indoor air pollutants.	STB-2.E.2	Indoor air pollutants that are classified as particulates include asbestos, dust, and smoke.
				STB-2.E.3	Indoor air pollutants can come from natural sources, human-made sources, and combustion.
				STB-2.E.4	Common natural source indoor air pollutants include radon, mold, and dust.
				STB-2.E.5	Common human-made indoor air pollutants include insulation, Volatile Organic Compounds (VOCs) from furniture, paneling and carpets; formaldehyde from building materials, furniture, upholstery, and carpeting; and lead from paints.
				STB-2.E.6	Common combustion air pollutants include carbon monoxide, nitrogen oxides, sulfur dioxide, particulates, and tobacco smoke.
				STB-2.E.7	Radon-222 is a naturally occurring radioactive gas that is produced by the decay of uranium found in some rocks and soils.
		STB-2.F	Describe the effects of indoor air pollutants.	STB-2.F.1	Radon gas can infiltrate homes as it moves up through the soil and enters homes via the basement or cracks in the walls or foundation. It is also dissolved in groundwater that enters homes through a well.
				STB-2.F.2	Exposure to radon gas can lead to radon induced lung cancer, which is the second leading cause of lung cancer in America.
7.6	Reduction of Air Pollutants	STB-2.G	Explain how air pollutants can be reduced at the source.	STB-2.G.1	Methods to reduce air pollutants include regulatory practices, conservation practices, and alternative fuels.
				STB-2.G.2	A vapor recovery nozzle is an air pollution control device on a gasoline pump that prevents fumes from escaping into the atmosphere when fueling a motor vehicle.
				STB-2.G.3	A catalytic converter is an air pollution control device for internal combustion engines that converts pollutants (CO, NOx, and hydrocarbons) in exhaust into less harmful molecules (CO_2, N_2, O_2, and H_2O).
				STB-2.G.4	Wet and dry scrubbers are air pollution control devices that remove particulates and/or gases from industrial exhaust streams.
				STB-2.G.5	Methods to reduce air pollution from coal burning power plants include scrubbers and electrostatic precipitators.
7.7	Acid Rain	STB-2.H	Describe acid deposition.	STB-2.H.1	Acid rain and deposition is due to nitrogen oxides and sulfur oxides from anthropogenic and natural sources in the atmosphere.
				STB-2.H.2	Nitric oxides that cause acid deposition come from motor vehicles and coal-burning power plants. Sulfur dioxides that cause acid deposition come from coal-burning power plants.
		STB-2.I	Describe the effects of acid deposition on the environment.	STB-2.I.1	Acid deposition mainly affects communities that are downwind from coal-burning power plants.
				STB-2.I.2	Acid rain and deposition can lead to the acidification of soils and bodies of water and corrosion of human-made structures.
				STB-2.I.3	Regional differences in soils and bedrock affect the impact that acid deposition has on the region—such as limestone bedrock's ability to neutralize the effect of acid rain on lakes and ponds.

7.8	Noise Pollution	STB-2.J	Describe human activities that result in noise pollution and its effects.	STB-2.J.1	Noise pollution is sound at levels high enough to cause physiological stress and hearing loss.
				STB-2.J.2	Sources of noise pollution in urban areas include transportation, construction, and domestic and industrial activity.
				STB-2.J.3	Some effects of noise pollution on animals in ecological systems include stress, the masking of sounds used to communicate or hunt, damaged hearing, and causing changes to migratory routes.

KEY UNDERSTANDINGS AND QUESTIONS

Key Understandings

- ❑ STB-2: Human activities have physical, chemical, and biological consequences for the atmosphere.
- ❑ Air Pollution sources include ones that are easy to locate on a map (point source) and ones that a very spread out and numerous (non point source).
- ❑ Air pollutants come from both natural sources (volcanoes, wildfires, dust storms) and human activities (combustion of fossil fuels, industrial emissions, transportation).
- ❑ The Clean Air Act (CAA) established national standards to reduce harmful pollutants and protect public health.
- ❑ The EPA regulates six criteria pollutants: carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter ($PM_{2.5}$ & PM_{10}), ground-level ozone (O_3), and lead (Pb).
- ❑ Air pollutants can be visible (smoke, dust) or invisible (ozone, carbon monoxide, nitrogen oxides).
- ❑ Both natural processes (volcanoes, wildfires, respiration, dust storms) and human activities (burning fossil fuels, industry, agriculture, transportation) release air pollutants.
- ❑ Air Pollution can be solids (PM) or gases (SO_X, NO_X, CO)
- ❑ Particulates ($PM_{10\text{ and }}$ $PM_{2.5}$) vary a great deal in size and the smaller the size the bigger the human health threats
- ❑ Sulfur Dioxide (SO_2) and is a main contributor to acid precipitation
- ❑ NO_x (includes NO, nitrous oxide, and NO_2, nitrogen dioxide) is also a contributor to acid precipitation
- ❑ Carbon Monoxide (CO) is formed during combustion
- ❑ Primary pollutants (NO_x, VOCs, and SO_2) are directly emitted from sources such as vehicles and power plants.
- ❑ Secondary pollutants (ozone, nitric acid, sulfuric acid, and PANs) form in the atmosphere through chemical reactions between primary pollutants and sunlight, water, or oxygen.
- ❑ Photochemical smog results when sunlight reacts with NO_x and VOCs, producing ozone and other toxic compounds.
- ❑ Acid deposition forms when sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react with water vapor, creating acids that fall to Earth as rain, snow, or dust.
- ❑ Smog and acid rain are both anthropogenic and can be mitigated through cleaner energy, emission controls, and regulation**.**
- ❑ Photochemical smog forms when sunlight reacts with nitrogen oxides (NO_x) and volatile organic compounds (VOCs) released by vehicles, industrial activity, and fuels.
- ❑ The reaction produces ground-level ozone (O_3) and other secondary pollutants.
- ❑ Smog formation depends on weather, geography, and human activity — especially in warm, sunny, and high-traffic cities (e.g., Los Angeles, Mexico City, Beijing).
- ❑ Health effects include respiratory irritation, asthma, eye irritation, and reduced lung function.
- ❑ Environmental effects include damage to plant tissues and reduced photosynthesis.
- ❑ Photochemical smog forms when sunlight reacts with nitrogen oxides (NO_x) and volatile organic compounds (VOCs) released by vehicles, industrial activity, and fuels.
- ❑ The reaction produces ground-level ozone (O_3) and other secondary pollutants.

- ❑ Smog formation depends on weather, geography, and human activity — especially in warm, sunny, and high-traffic cities (e.g., Los Angeles, Mexico City, Beijing).
- ❑ Health effects include respiratory irritation, asthma, eye irritation, and reduced lung function.
- ❑ Environmental effects include damage to plant tissues and reduced photosynthesis.
- ❑ **Thermal inversions** occur when a **layer of warm air traps cooler air beneath it**, preventing pollutants from dispersing vertically.
- ❑ During a thermal inversion, the normal temperature gradient in the atmosphere is altered as the air temperature at the Earth's surface is cooler than the air at higher altitudes.
- ❑ Thermal inversion traps pollution close to the ground, especially smog and particulates.
- ❑ Methods to reduce air pollutants include regulatory practices, conservation practices, and alternative fuels.
- ❑ A vapor recovery nozzle is an air pollution control device on a gasoline pump that prevents fumes from escaping into the atmosphere when fueling a motor vehicle.
- ❑ A catalytic converter is an air pollution control device for internal combustion engines that converts pollutants (CO, NOx, and hydrocarbons) in exhaust into less harmful molecules (CO_2, N_2, O_2, and H_2O).
- ❑ Wet and dry scrubbers are air pollution control devices that remove particulates and/or gases from industrial exhaust streams.
- ❑ Methods to reduce air pollution from coal burning power plants include scrubbers and electrostatic precipitators.
- ❑ Indoor air pollutants that are classified as particulates include asbestos, dust, and smoke.
- ❑ **Asbestos** – from insulation and building materials.
- ❑ **Particulate matter (PM)** – from smoke, candles, cooking, or dust.
- ❑ **Mold, pollen, pet dander** – from biological sources.
- ❑ Common human-made indoor air pollutants include insulation, Volatile Organic Compounds (V**OCs**) from furniture, paneling and carpets; formaldehyde from building materials, furniture, upholstery, and carpeting; and lead from paints.
- ❑ **Formaldehyde** – from furniture, pressed wood, and carpets.
- ❑ **VOCs** are both an outdoor air quality and an indoor air quality concern
- ❑ Common combustion air pollutants include carbon monoxide, nitrogen oxides, sulfur dioxide, particulates, and tobacco smoke.
- ❑ **Carbon monoxide (CO)** – from incomplete combustion (gas stoves, fireplaces) and is a human health hazard it is odorless and can suffocate people (an asphyxiant) because it binds with hemoglobin and takes the place of oxygen.
- ❑ **Radon (Rn)-222** is a naturally occurring radioactive gas that is produced by the decay of uranium found in some rocks and soils.
- ❑ **Radon** gas can infiltrate homes as it moves up through the soil and enters homes most commonly via the basement, or cracks in the walls or foundation. It is also dissolved in groundwater that enters homes from a well.
- ❑ Exposure to **radon** gas can lead to radon induced lung cancer, which is the second leading cause of lung cancer in America.

Key Questions

BIG IDEA 4 – *Sustainability*

- What are the major sources of air pollution in modern societies?
- Why do some cities have more severe air pollution problems than others?
- Does wind reduce the amount of air pollution?

- Which air pollutants are the biggest threats to human health, and which are the biggest threats to the environment?
- How can air pollution, or the effects of air pollution be reduced?

ROADMAP

AT A Glance: Unit #:				
Day	**Date**	**Lesson**	**Lesson Title**	**Lesson & Pacing Notes**
1		01	Into to Air Pollution	
2		02	Intro to Air Pollution	
3		03	Visible & Invisible Pollutants	
4		04	Secondary Pollutants	
5		05	Case Study – Photochemical Smog	
6		06	Lab – Acid Rain	
7		07	Lab – Acid Rain	
8		08	Lab – Acid Rain	
9		09	Reducing Air Pollution	
10		10	Indoor Air Pollution	
11		11	Flex/ Review	
12	**TX_SCI_APEnvironmentalScience_S25_UE6**			
13	**Succes Day (time permitting)**			

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
Day 1-2 **Intro to Air Pollution**	**STANDARD(s):** **Topic 7.1: Intro to Air Pollution** **STB-2.A - Identify** the sources and effects of air pollutants. **SWBAT**: **Describe** the air pollutants regulated by the clean air act and the recent trends for these pollutants **Disciplinary Literacy Focus:**  	**KEY UNDERSTANDINGS CHECKLIST:** ❑ Air pollutants come from both natural sources (volcanoes, wildfires, dust storms) and human activities (combustion of fossil fuels, industrial emissions, transportation). ❑ The Clean Air Act (CAA) established national standards to reduce harmful pollutants and protect public health. ❑ The EPA regulates six criteria pollutants: carbon monoxide (CO), sulfur dioxide (SO_2), nitrogen oxides (NO_x), particulate matter ($PM_{2.5}$ & PM_{10}), ground-level ozone (O_3), and lead (Pb). **LESSON CONTEXT FOR LESSON MASTERY:** Students will work in pairs to complete a WebQuest researching the Clean Air Act and Criteria Pollutants using the EPA website. *NOTE - Students may not have enough time to finish this webquest during this class period but there is additional flex time built into this unit or can be assigned as homework.* **LOOK-FORS 🔍 (What to observe students doing or producing)** During student work discussions, look for evidence that students can: • Describing each of the six major air pollutants. • Making connections between air pollutant sources → pollutants → effects (e.g., cars → NO_x → smog & respiratory problems). • Discussion about air pollutants' effects on human health and environmental effects. **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Thinking that all air pollution is manmade (anthropogenic) but forgetting to identify that natural sources like volcanoes also create air pollution. • Carbon dioxide is a criteria air pollutant. CO_2 is not a conventional air pollutant and is not regulated under the Clean Air Act's six criteria pollutants, but does have significant environmental impacts because it is a greenhouse gas. **MAKING CONNECTIONS**	**TEACHER BACKGROUND CONTENT RESOURCES**. Smedes APES 7.1 AP Classroom 7.1 Video#1 AP Classroom 7.1 Video#2 AP Classroom 7.1 Video#3

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Clean Air Act was created to address six Criteria Pollutants (and still does) and has been revised many times to address many specific air pollution concerns • Criteria Pollutants have all dramatically decreased since the implementation of Clean Air Act policies, other than tropospheric ozone • Tropospheric Ozone is an air pollutant that helps to create photochemical smog and is a respiratory irritant when inhaled by humans, but Stratospheric Ozone, called the Ozone Layer, helps to protect humans and plants from harmful UV radiation from sunlight – Hence the saying **Ozone is good up high and bad nearby**	
Day 3 **Visible and Invisible Pollutants**	**STANDARD(s):** **Topic 7.1: Intro to Air Pollution** **STB-2.A - Identify** the sources and effects of air pollutants. **SWBAT: Describe** common visible and invisible air pollutants as natural or anthropogenic using an online activity. **Disciplinary Literacy Focus:**  	**KEY UNDERSTANDINGS CHECKLIST:** ❑ Air pollutants can be visible (smoke, dust) or invisible (ozone, carbon monoxide, nitrogen oxides). ❑ Both natural processes (volcanoes, wildfires, respiration, dust storms) and human activities (burning fossil fuels, industry, agriculture, transportation) release air pollutants. ❑ Air Pollution can be solids (PM) or gases (SO_X, NO_X, CO) ❑ Particulates ($PM_{10\ and}$ $PM_{2.5}$) vary a great deal in size and the smaller the size the bigger the human health threats ❑ Sulfur Dioxide (SO_2) and is a main contributor to acid precipitation ❑ NO_x (includes NO, nitrous oxide, and NO_2, nitrogen dioxide) is also a contributor to acid precipitation ❑ Carbon Monoxide (CO) is formed during combustion **LESSON CONTEXT FOR LESSON MASTERY:** Students will work in pairs to complete the online activity High-Adventure Science: Will the air be clean enough to breathe? - Module 4 - Visible and Invisible Pollutants. Students will continue to be introduced to common air pollutants by categorizing them as visible or invisible with a focus making claims supported by evidence from graphs, charts, and text. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Correctly differentiating between natural and anthropogenic sources of pollutants.	**Teachers need to go register (for free) at High Adventure Science – Concord Consortium to access this online lesson.** Module 4 – Visible and Invisible Pollutants **TEACHER BACKGROUND CONTENT RESOURCES.** Smedes APES 7.1 Smedes APES 7.4

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Accurately describing sources or air pollutants and affect living organisms and/or the environment. • Describe why some pollutants are visible and others are not. **COMMON MISCONCEPTIONS ⚑ (Historical/widespread misunderstandings)** • Students confuse smoke and smog are the same thing. Smoke is visible particles; **smog** is a chemical mixture often invisible. • Natural pollution don't negatively affect the environment, but Natural pollutants can still impact air quality and health (e.g., volcanic ash, wildfire smoke). **Making Connections** A primary anthropogenic source of SO_x is from the burning of fossil fuels and as we continue to deplete the highest-grade fossil fuels (like anthracite coal) and must use lower grade fuels (like bituminous of lignite). These contain less usable energy per volume, so we must burn more to create the same amount of usable energy, AND they contain a higher percentage of impurities like Sulfur, so they create more air pollution.	
Day 4 **Secondary Pollutants**	**STANDARD(s)** **Topic 7.2: Photochemical Smog** **STB-2.B - Explain** the causes and effects of photochemical smog and methods to reduce it. **Topic 7.7: Acid Rain** **STB-2.H - Describe** acid deposition. **STB-2.I - Describe** the effects of acid deposition on the environment.	**KEY UNDERSTANDINGS CHECKLIST:** ❑ Primary pollutants (NO_x, VOCs, and SO_2) are directly emitted from sources such as vehicles and power plants. ❑ Secondary pollutants (ozone, nitric acid, sulfuric acid, and PANs) form in the atmosphere through chemical reactions between primary pollutants and sunlight, water, or oxygen. ❑ Photochemical smog results when sunlight reacts with NO_x and VOCs, producing ozone and other toxic compounds. ❑ Acid deposition forms when sulfur dioxide (SO_2) and nitrogen oxides (NO_x) react with water vapor, creating acids that fall to Earth as rain, snow, or dust. ❑ Smog and acid rain are both anthropogenic and can be mitigated through cleaner energy, emission controls, and regulation. **LESSON CONTEXT FOR LESSON MASTERY:**	Teachers need to go register (for free) at High Adventure Science – Concord Consortium to access this online lesson. Module 5 – Pollutants Making More Pollutants **TEACHER BACKGROUND CONTENT RESOURCES**. Smedes APES 7.2 AP Classroom 7.2 Video #1 AP Classroom 7.2 Video#2

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
	SWBAT: Explain how secondary pollutants are created by exploring the chemical reactions that happen with primary pollutants in the atmosphere. **Disciplinary Literacy Focus:** 	Students will work in pairs to complete the online activity High-Adventure Science: Will the air be clean enough to breathe? - Module 5 – Pollutants making more pollutants. Students answer questions using data analysis, diagram analysis and by making claims with justification for their answers. Students should be encouraged to discuss all questions and answers with table partners using Accountable Talk Moves. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Differentiating between primary and secondary pollutants. • Creating or describing diagrams of secondary air pollutant formation in the atmosphere. • Describing the chemical reactions that create secondary air pollution **COMMON MISCONCEPTIONS ⚑ (Historical/widespread misunderstandings)** • Thinking that ozone is always bad. **Stratospheric ozone** protects the Earth from harmful UV light; **ground-level ozone** (a secondary pollutant) is harmful. **MAKING CONNECTIONS** • Secondary Pollutants are created by one or more chemical reactions between primary pollutants and other chemicals in the environment and are typically overlooked until they begin to have significant negative environmental or human health impacts. • Formation of secondary pollutants is heavily influenced by abiotic factors • Tropospheric ozone is one of the air pollutants that is included in the Air Quality Index (AQI) and students may notice that there are ozone alerts in their area (especially in sunny southern locations) and that these alerts tend to occur in spring and summer months, when there is the most sunlight available	
Day 5	**STANDARD(s)** **Topic 7.2: Photochemical Smog**	**KEY UNDERSTANDINGS CHECKLIST:** ❑ Photochemical smog forms when sunlight reacts with nitrogen oxides (NO_x) and volatile organic compounds (VOCs) released by vehicles, industrial activity, and fuels.	

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
Photochemical Smog Case Study	**Explain** the causes and effects of photochemical smog and methods to reduce it Describe the factors that lead to increased rates of photochemical smog in certain cities and regions. **Describe** the effects of photochemical smog on human health and the environment **Disciplinary Literacy Focus:**  	❑ The reaction produces ground-level ozone (O_3) and other secondary pollutants. ❑ Smog formation depends on weather, geography, and human activity — especially in warm, sunny, and high-traffic cities (e.g., Los Angeles, Mexico City, Beijing). ❑ Health effects include respiratory irritation, asthma, eye irritation, and reduced lung function. ❑ Environmental effects include damage to plant tissues and reduced photosynthesis. **LESSON CONTEXT FOR LESSON MASTERY:** Students will explore the Three C's (Causes, Chemicals, Consequences) for the secondary air pollutant photochemical smog using a case study to provide additional context for making connections with other APES topics. Students will identify and describe abiotic factors that increase photochemical smog formation and Explain the chemical process that forms photochemical smog. Teachers should reference the teacher's version of the case study for the correct answers and extra information to share with students. **LOOK-FORS 🔍 (What to observe students doing or producing)** • During lessons, labs, or discussions, look for students who can: • Describe the **sequence**: NO_x + VOCs + sunlight → O_3 + PANs (secondary pollutants). • Use diagrams or models to show the formation of smog. **COMMON MISCONCEPTIONS ⚑ (Historical/widespread misunderstandings)** • Students think that ozone is only found/created in the upper atmosphere. **Ground-level ozone** is a harmful secondary pollutant that contributes to photochemical smog. • Smog is just fog mixed with smoke. Photochemical smog is created by a **chemical reaction** between sunlight, NO_x, and VOCs. **MAKING CONNECTIONS**	**TEACHER BACKGROUND CONTENT RESOURCES** Smedes APES 7.2 AP Classroom 7.2 Video #1 AP Classroom 7.2 Video#2

<table>
<tr><th>Lesson</th><th>Objective(s) and Standard(s)</th><th>Instructional Notes</th><th>Resources</th></tr>
<tr><td></td><td></td><td>• Photochemical smog is more common in cities with lots of sunshine and a lot if commuter traffic because sunlight and VOCs are two of the criteria for creating photochemical smog as a secondary pollutant.</td><td></td></tr>
<tr><td>Day 6

Acid Rain Labs Day 1

Day 7

Acid Rain Labs Day 2

Day 8

Acid Rain Labs Day 3</td><td>STANDARD(s)

Topic 7.7: Acid Rain
Describe acid deposition.
Describe the effects of acid deposition on the environment.

Explain the environmental impacts of acid rain.

Disciplinary Literacy Focus

Planning and Carrying Out Investigations</td><td>KEY UNDERSTANDINGS CHECKLIST:
❑ Acid deposition refers to all forms of acidic moisture (rain, snow, fog, or dry particles) falling to Earth due to air pollution.
❑ It is caused mainly by sulfur dioxide (SO_2) and nitrogen oxides (NO_x) reacting with water vapor in the atmosphere to form sulfuric acid (H_2SO_4) and nitric acid (HNO_3).
❑ Acid depositions can occur as wet depositions (rain, snow, fog) or dry depositions (acidic particles or gases settling on surfaces).
❑ Experiment 1 will be set up on Day 1 of these labs and then data will be collected on Day 3 – to provide 48 hours before data collection
❑ Day 2 will include some additional station lab activities

LESSON CONTEXT FOR LESSON MASTERY:
Students will set up the acid rain experiment on Day 06 and then collect data, make calculations and answer analysis questions on Day 08 because this lab needs about 48 hours to give good results. On Day 07 the teacher will conduct demonstrations that simulate acid rain and allow students to observe and describe the formation and effects of acid rain using a chemical indicator (bromothymol blue and/or pH sensors). Teachers may also consider including some independent research questions to explore the negative environmental effects and the potential solutions to help mitigate acid rain in greater detail.

LOOK-FORS 🔍 (What to observe students doing or producing)
• Identify SO_2 and NO_x as primary pollutants and H_2SO_4, HNO_3 as secondary pollutants.
• Correctly explain or diagram the acid rain formation process.
• Describe how acid deposition affects lakes, forests, and organisms.

COMMON MISCONCEPTIONS ⚑ (Historical/widespread misunderstandings)</td><td>Day06-08-U7-AirPollution-Lab-AcidRain.

Material (per group) s:
• 1 cup vinegar
• 1 cup lemon juice
• 1 cup distilled water
• 3 medium size pieces of eggshell
• 3 medium sized leaves
• 3 metal paperclips
• 3 clear glass or plastic cups
• Masking tape and pen (shared)
• Electronic balances

TEACHER BACKGROUND CONTENT RESOURCES.
Khan Academy – Acid Rain
NatGeo -Acid Rain Explained

Smedes APES 7.7</td></tr>
</table>

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• Acid precipitation only affects water quality and/or aquatic organisms. Acid rain also damages plant leaves, make nutrients less available to plants, and damages buildings, and monuments. • Regular precipitation has neutral or basic pH (but it is normal for precipitation to be slightly acidic - pH around 5.5-5.6 because of dissolved CO_2 Carbonic Acid) • Acid precipitation only includes rain. Acid rain can also fall in the form of snow or sleet or as small solid salt particles. **MAKING CONNECTIONS** • All rain is slightly acidic (pH around 5.5-5.6 because of dissolved CO_2) but acid rain has a much lower pH, typically 4.2-4.6. • One primary pollutant that creates acid rain is SOX and one of the largest sources of SOX pollution is the burning of coal.	
Day 9 **Reducing Air Pollution**	**STANDARD(s):** **Topic 7.6: Reduction of Air Pollutants** **STB-2.G - Explain** how air pollutants can be reduced at the source. **Topis 7.3: Thermal Inversion** **STB-2.C - Describe** thermal inversion and its relationship with pollution. **SWBAT: explain** how thermal inversions are created and describe how they impact air pollution by analyzing diagrams of thermal inversion and	**KEY UNDERSTANDINGS CHECKLIST:** ❑ **Thermal inversions** occur when a **layer of warm air traps cooler air beneath it**, preventing pollutants from dispersing vertically. ❑ During a thermal inversion, the normal temperature gradient in the atmosphere is altered as the air temperature at the Earth's surface is cooler than the air at higher altitudes. ❑ Thermal inversion traps pollution close to the ground, especially smog and particulates. ❑ Methods to reduce air pollutants include regulatory practices, conservation practices, and alternative fuels. ❑ A vapor recovery nozzle is an air pollution control device on a gasoline pump that prevents fumes from escaping into the atmosphere when fueling a motor vehicle. ❑ A catalytic converter is an air pollution control device for internal combustion engines that converts pollutants (CO, NOx, and hydrocarbons) in exhaust into less harmful molecules (CO2, N2, O2, and H2O). ❑ Wet and dry scrubbers are air pollution control devices that remove particulates and/or gases from industrial exhaust streams. ❑ Methods to reduce air pollution from coal burning power plants include scrubbers and electrostatic precipitators.	**TEACHER BACKGROUND CONTENT RESOURCES**. Smedes APES 7.3 Smedes APES 7.6 Khan Academy – Reduction of Air Pollutants AP Daily Video 7.3 – Thermal Inversion AP Daily Video 7.6 – 1 – regulations, conservation, alternative fuels AP Daily Video 7.6 – 2 AP Daily Video 7.6 - 3

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
	comparing with regular atmospheric conditions. **SWBAT: describe** the advantages and disadvantages of common pollution reducing technologies by reading and discussing articles with table partners. **Disciplinary Literacy Focus:**  	**LESSON CONTEXT FOR LESSON MASTERY:** Students will start with an extended Do Now to reinforce Thermal Inversions that were briefly introduced in a previous lesson. Students will explore different strategies to reduce air pollution with a focus on the differences between creating less air pollution in the first-place vs removing/filtering air pollution before it can be released into the atmosphere. Students will work in patterns to explain how different technologies reduce air pollution from particular types of sources using online videos and readings. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Explain source reduction strategies and link each to a specific pollutant (e.g., scrubbers → SO_2, catalytic converters → NO_x). • Draw or label a diagram of a thermal inversion, showing warm and cool air layers. **COMMON MISCONCEPTIONS 🚩 (Historical/widespread misunderstandings)** • Inversions create air pollution. They can increase the amount of air pollution in an area by trapping air pollutants and not letting it disperse high enough into the atmosphere to move to other regions. • Air pollution is decreased by using tall smokestacks. Tall smokestacks help pollution reach higher into the atmosphere and get dispersed, which decreases the amount of pollution in the region of the source but does not decrease the amount of pollution released into the atmosphere. **MAKING CONNECTIONS** • Thermal inversion can act like a container that holds air pollution, and it can accumulate up, and is the result of an unusually cool layer of air in the lower troposphere • Most energy conservation techniques, especially public transportation, also reduce air pollution that is created by burning fossil fuels • BEV and HFEV reduce air pollution when the energy used to create electricity/hydrogen fuel is renewable by eliminating car exhaust • Renewable energy reduces air pollution created by coal power plants	

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		• It is always easier to not make a mess (create less air pollution) than it is to clean up a mess (remove the air pollution from exhaust)	
Day 10 **Indoor Air Pollution**	**STANDARD(s):** **Topic 7.5 – Indoor Air Pollutants** **STB-2.E Identify** indoor air pollutants. **STB-2.F Describe** the effects of indoor air pollutants. **SWBAT: Describe** the sources and health effects of common indoor air pollutants. **Disciplinary Literacy Focus:** 	**KEY UNDERSTANDINGS CHECKLIST:** ❑ Indoor air pollutants can come from natural sources, human-made sources, and combustion. ❑ Indoor air pollutants that are classified as particulates include asbestos, dust, and smoke. ❑ **Asbestos** – from insulation and building materials. ❑ **Particulate matter (PM)** – from smoke, candles, cooking, or dust. ❑ **Mold, pollen, pet dander** – from biological sources. ❑ Common human-made indoor air pollutants include insulation, Volatile Organic Compounds (V**OCs**) from furniture, paneling and carpets; formaldehyde from building materials, furniture, upholstery, and carpeting; and lead from paints. ❑ **Formaldehyde** – from furniture, pressed wood, and carpets. ❑ **VOCs** are both an outdoor air quality and an indoor air quality concern ❑ Common combustion air pollutants include carbon monoxide, nitrogen oxides, sulfur dioxide, particulates, and tobacco smoke. ❑ **Carbon monoxide (CO)** – from incomplete combustion (gas stoves, fireplaces) and is a human health hazard it is odorless and can suffocate people (an asphyxiant) because it binds with hemoglobin and takes the place of oxygen. ❑ **Radon (Rn)-222** is a naturally occurring radioactive gas that is produced by the decay of uranium found in some rocks and soils. ❑ **Radon** gas can infiltrate homes as it moves up through the soil and enters homes most commonly via the basement, or cracks in the walls or foundation. It is also dissolved in groundwater that enters homes from a well. ❑ Exposure to **radon** gas can lead to radon induced lung cancer, which is the second leading cause of lung cancer in America. **LESSON CONTEXT FOR LESSON MASTERY:** Students will explore the Three C's (causes, chemicals and consequences) of different indoor air pollutants working in small groups through a digital station	**TEACHER BACKGROUND CONTENT RESOURCES**. Khan Academy – Indoor Air Pollutants Smedes APES 7.5

Lesson	Objective(s) and Standard(s)	Instructional Notes	Resources
		rotation. Teacher should add a little extra context to some of the indoor air pollutants and/or help students make connections between indoor air pollution and outdoor air pollution with guiding questions during lesson debrief. **LOOK-FORS 🔍 (What to observe students doing or producing)** • Correctly describing/matching pollutants with their sources and effects. **COMMON MISCONCEPTIONS ⚑ (Historical/widespread misunderstandings)** • Students think that Indoor air is always cleaner than outdoor air. • Indoor air can be 2–5 times more polluted due to trapped gases and poor ventilation. • Students assume that Air pollution only happens in cities • Rural homes may **have radon, wood smoke, and pesticide residues.** **MAKING CONNECTIONS** • Indoor air pollution can often be as big a source of pollutants as outdoor air, especially because in order to increase the energy efficiency of buildings all of the air leaks need to be removed as much as possible which reduces air ventilation through the building, meaning that air pollutants released inside the building can remain there for a long time and build increase in concentration over time.	
Day 11 **Flex/Review**	**Flex/review Options** • Albert.IO teacher made quiz review • Progress Check MC Questions – 24 MCQ – 27 min (some questions already used as exit tickets) • Progress Check FRQ (22-23 min students to individually take FRK and 30 min peer grade and review) ○ Experimental Design – 7.1: Introduction to Air Pollution – 7.5: Indoor Air Pollutants		
Day 12 **Unit 07 Exam**	**Unit Exam 07– Atmospheric Pollution** **TX_SCI_APEnvironmentalScience_S26_UE7**		

VERTICAL STANDARDS

This section details the **progression** of key student expectations/standards** in the courses **before** and **after** this course. This will help you understand what **prior knowledge skills to build upon** and guide you in knowing what **skills you are preparing your students** for in the subsequent course.

BEFORE AP Environmental Science

Grades 4-5

3-5(11) Earth and Space. The student understands how natural resources are important and can be managed. The student is expected to:

- 4(11)(A) identify and explain advantages and disadvantages of using Earth's renewable and nonrenewable natural resources such as wind, water, sunlight, plants, animals, coal, oil, and natural gas;
- 4(11)(B) explain the critical role of energy resources to modern life and how conservation, disposal, and recycling of natural resources impact the environment; and

Grade 6

6(11) Earth and space. The student understands how resources are managed. The student is expected to:

- 6(11)(A) research and describe why resource management is important in reducing global energy, poverty, malnutrition, and air and water pollution, and
- 6(11)(B) explain how conservation, increased efficiency, and technology can help manage air, water, soil, and energy resources.

Grade 7

7(11) Earth and space. The student understands how human activity can impact the hydrosphere. The student is expected to:

- 7(11)(A) analyze the beneficial and harmful influences of human activity on groundwater and surface water in a watershed; and
- 7(11)(B) describe human dependence and influence on ocean systems and explain how human activities impact these systems.

Grade 8

8(11) Earth and space. The student knows that natural events and human activity can impact global climate. The student is expected to:

- 8(11)(A) use scientific evidence to describe how natural events, including volcanic eruptions, meteor impacts, abrupt changes in ocean currents, and the release and absorption of greenhouse gases influence climate;
- 8(11)(B) use scientific evidence to describe how human activities, including the release of greenhouse gases, deforestation, and urbanization, can influence climate; and
- 8(11)(C) describe the carbon cycle.

Pre-AP Biology (Grade 8 or 9)
Pre-AP Chemistry (Grade 9 or 10)

After AP Environmental Science

AP Biology (Grade 10, 11 or 12)
AP Chemistry

VOCABULARY GLOSSARY

Domain-specific words and definitions for this unit.

Key Content Vocabulary
Point Source Pollution – *a source of pollution that can be easily pointed to (eg – power plants, industrial factories)* ***Non Point Source Pollution –*** *a source of pollution that does not have a clear location (eg – automobiles, farms, etc)* ***Primary Air Pollutant –*** *pollutants that are released directly into the atmosphere from a source (most common – sulfur oxides (SOx), nitrogen oxides (NOx), Carbon Monoxide, Volatile Organic Compounds (VOCs), Particulates/Particulate Matter)* ***Secondary Air Pollutant –*** *pollutants formed as the result primary pollutants reacting with molecules in the atmosphere to form a new pollutant (commonly – photochemical smog, acid precipitation, ozone (O_3))* ***Photochemical Smog –*** ***Acid Precipitation -*** *any form of precipitation that is unusually acidic, meaning that it has elevated levels of hydrogen ions than regular precipitation (low pH). Acid precipitation usually has a pH of 4-5.* ***Clean Air Act –*** *the United States' primary federal air quality law, intended to reduce and control air pollution nationwide. Initially enacted in 1963 and amended many times since, it is one of the United States' first and most influential modern environmental laws.* *As with many other major U.S. federal environmental statutes, the Clean Air Act is administered by the U.S. Environmental Protection Agency (EPA), in coordination with state, local, and tribal governments.[1]:2–3 EPA develops extensive administrative regulations to carry out the law's mandates. The associated regulatory programs are often technical and complex. Among the most important, the National Ambient Air Quality Standards program sets standards for concentrations of certain pollutants in outdoor air; the National Emissions Standards for Hazardous Air Pollutants program sets standards for emissions of particular hazardous pollutants from specific sources. Other programs create requirements for vehicle fuels, industrial facilities, and other technologies and activities that impact air quality. Newer programs tackle specific problems, including acid rain, ozone layer protection, and climate change.* ***Criteria Pollutants –*** *the first six air pollutants recognized by the EPA as needing standards on a national level: Ground level ozone, particulate matter, Lead, Carbon Monoxide, Sulfur Oxides, Nitrogen Oxides.* ***Nitrogen Oxides (NO_x) –*** *Includes nitric oxide (NO), nitrous oxide (N_2O), and nitrogen dioxide (NO_2), all of which are covered in the NAAQS. NO_2 is the oxide measured and used as the indicator for the entire NO_x family as it is of the most concern due to its quick formation and contribution to the formation of harmful ground level ozone.* ***Sulfur Oxides (SO_x) –*** *SO_x refers to the oxides of sulfur, a highly reactive group of gases. SO_2 is of greatest interest and is used as the indicator for the entire SO_x family.* ***Particulates –*** *PM_{10}, coarse particles: 2.5 micrometers (µm) to 10 µm in size (although current implementation includes all particles 10 µm or less in the standard) and $PM_{2.5}$, fine particles: 2.5 µm in size or less.* ***Ozone (tropospheric) -*** *Ozone (O3) is a colorless, reactive oxidant gas that is a major constituent of atmospheric smog. Ground level ozone is formed in the air by the photochemical reaction of sunlight and nitrogen oxides (NOx), facilitated by a variety of volatile organic compounds (VOCs), which are photochemically reactive hydrocarbons.*

Thermal Inversion - *Also called a temperature inversion. Normally, air temperature decreases with an increase in altitude, but during an inversion warmer air is held above cooler air.[2]An inversion traps air pollution, such as smog, close to the ground.*
Radon – *a chemical element with the symbol Rn and atomic number 86. It is a radioactive, colorless, odorless, tasteless noble gas. Epidemiological studies have shown a clear link between breathing high concentrations of radon and incidence of lung cancer. Radon is a contaminant that affects indoor air quality worldwide.*
Carbon Monoxide - *Carbon monoxide consists of one carbon atom and one oxygen atom, and is a colorless, odorless, tasteless, flammable gas that is slightly less dense than air. The most common source of carbon monoxide is thermal combustion.*
Volatile Organic Compounds (VOCs) – *Volatile organic compounds (VOCs) are emitted as gases from certain solids or liquids. VOCs include a variety of chemicals, some of which may have short- and long-term adverse health effects. Concentrations of many VOCs are consistently higher indoors (up to ten times higher) than outdoors. VOCs are emitted by a wide array of products numbering in the thousands. Organic chemicals are widely used as ingredients in household products. Paints, varnishes and wax all contain organic solvents, as do many cleaning, disinfecting, cosmetic, degreasing and hobby products. Fuels are made up of organic chemicals.*
Wet Scrubber – *describes a variety of devices that remove pollutants from a furnace flue gas or from other gas streams. In a wet scrubber, the polluted gas stream is brought into contact with the scrubbing liquid, by spraying it with the liquid, by forcing it through a pool of liquid, or by some other contact method, so as to remove the pollutants.*
Dry Scrubber - *A dry or semi-dry scrubbing system, unlike the wet scrubber, does not saturate the flue gas stream that is being treated with moisture. Dry scrubbing systems are often used to remove acid gases (such as SO_2 and HCl) primarily from combustion sources.*
Electrostatic Precipitator – *A filter less device that removes fine particles, like dust and smoke, from a flowing gas using the force of an induced electrostatic charge minimally impeding the flow of gases through the unit.*
Catalytic Converter – *an exhaust emission control device that converts toxic gases and pollutants in exhaust gas from an internal combustion engine into less-toxic pollutants by catalyzing a redox reaction. Require high temperatures to effectively reduce automobile emissions.*

Related Vocabulary

Environmental Protection Agency (EPA) National Ambient Air Quality Standards (NAAQS) Air Quality Index (AQI) Vapor Recovery Nozzle	Photoreactive Indoor Air Quality (IAQ)		