**DEP Environmental Education Curricula**

**Lesson Plan**

**GRADE/LEVEL: Middle School**

**LESSON TITLE: Air Pollution**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Next Generation Science Standards** |  |  | | |
| **MS-LS2 Ecosystems: Interactions, Energy, Dynamics** | **MS-LS2-4** | Construct an argument supported by empirical evidence that changes to physical or biological components of an ecosystem affect populations. | | |
|  | **Science and Engineering Practices** | **Engaging in Argument from Evidence** – Construct an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation for a model for a phenomenon or a solution to a problem. | | |
|  | **Disciplinary Core Ideas** | **LS2.C: Ecosystems Dynamics, Functioning, and Resilience** – Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. | | |
|  | **Crosscutting Concepts** | **Stability and Change –** Small changes in one part of a system might cause large changes in another part. | | |
| **Objectives** | | | | |
|  |  | **Objective 1:** To observe how temperature inversions are formed and how inversions influence air pollution levels.  **Objective 2:** To discuss the health effects of air pollutants and how the Clean Air Act is a tool to reduce air pollution in the U.S.  **Objective 3:** To introduce students to actions that they and/or other members of our community can take to reduce air pollution. | | |
| **Vocabulary** |  |  | | |
|  |  | **Air Quality Index (AQI)** A guide for reporting daily air quality that indicates how clean or polluted the air is in a particular area and identifies potential health impacts. The AQI works as a measuring stick that runs from 0 to 500. The higher the AQI value, the greater the level of air pollution and the greater the health risk.  **Attainment Area** A geographic area with air quality that is cleaner than the primary standard.  **Carbon Monoxide - (CO) -** A colorless, odorless, poisonous gas and one of six “criteria pollutants” for which the U.S. Environmental Protection Agency (EPA) has established protective standards. Carbon monoxide forms when the carbon in fuels does not completely burn.  **Certified/Non-Certified Wood Stove**  A certified wood stove is any wood stove manufactured since 1988. Since this time, EPA has required manufacturers of wood stoves to certify that their wood stoves offered for sale in the United States comply with particulate emissions guidelines in the Clean Air Act. Certified wood stoves are cleaner and more efficient than a wood stove manufactured before 1988. A noncertified wood stove is any stove manufactured before 1988. These stoves do not burn as clean and emit more air pollution.  **Combustion** The process of burning.  **Convection** The vertical movement of heat within the atmosphere. The idea that warm air rises and cool air sinks.  **Emission** The act or instance of discharging (emitting) something into the air, such as by an internal combustion engine (e.g., a vehicle).  **Emit** To give off or discharge.  **Exhaust** The fumes or gases released from an engine.  **Inversion (“Thermal” or “Temperature”)** A reversal in the normal temperature layers. A layer of warm air settles on top of a layer of cold air, and the cold air ends up trapped underneath.  **Nonattainment Area** Areas that do not meet the primary standard for air quality.  **Particulate Pollution (“particulate matter” or PM)** Small particles suspended in the air including dust, dirt, soot, smoke, and liquid droplets.  **Pollutant** Any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems.  **Primary Standards** The set limits for air quality based to protect human health.  **Secondary Standards** The set of air pollution limits intended to prevent environmental and property damage. | | |
| **Background** |  |  | | |
| **Teacher Version**  Selected Materials from … | | **Source:** The Plain English Guide to the Clean Air Act https://www.epa.gov/sites/production/files/2015-08/documents/peg.pdf | | |
| **Background**  Air pollution can damage trees, crops, and other plants in our natural environment. Air pollution also reduces how far you can see in national parks and cities, it can even interfere with aviation.  In 1970, Congress created the Environmental Protection Agency (EPA) and passed the Clean Air Act, giving the federal government authority to clean up air pollution in this country. Since then, the EPA, states, tribes, local governments, industry, and environmental groups have worked to establish a variety of programs to reduce air pollution levels across America.  The Clean Air Act has helped change the way many of us work or do business.  **Air Pollution and Your Health**  Breathing polluted air can make your eyes and nose burn. It can irritate your throat and make breathing difficult. In fact, pollutants like tiny airborne particles and ground-level ozone can trigger respiratory problems, especially for people with asthma. Asthma sufferers can be severely affected by air pollution. It can also aggravate health problems for the elderly and others with heart or respiratory diseases. Some toxic chemicals released in the air such as benzene or vinyl chloride are highly toxic and can cause cancer, birth defects, long term injury to the lungs, as well as brain and nerve damage. And in some cases, breathing these chemicals can even cause death.  Other pollutants make their way up into the upper atmosphere, causing a thinning of the protective ozone layer. This has led to changes in the environment and dramatic increases in skin cancers and cataracts (eye damage).  **Air Pollution and the Environment**  Air pollution isn’t just a threat to our health, it also damages our environment. Toxic air pollutants and the chemicals that form acid rain and ground-level ozone can damage trees, crops, wildlife, lakes and other bodies of water. Those pollutants can also harm fish and other aquatic life.  **Air Pollution and the Economy**  The health, environmental, and economic impacts of air pollution are significant. Each day, air pollution causes thousands of illnesses leading to lost days at work and school. Air pollution also reduces agricultural crop and commercial forest yields by billions of dollars each year.  **Progress**  By reducing air pollution, the Clean Air Act has led to significant improvements in human health and the environment in the U.S. Since 1970, the six commonly found air pollutants have decreased by more than 50 percent, air toxics from large industrial sources, such as chemical plants, petroleum refineries, and paper mills have been reduced by nearly 70 percent, new cars are more than 90 percent cleaner and will be even cleaner in the future, and production of most ozone-depleting chemicals has ceased. At the same time, the U.S. gross domestic product, or GDP, has tripled, energy consumption has increased by 50 percent, and vehicle use has increased by almost 200 percent.  **History of the Clean Air Act**  The original Clean Air of 1963 established funding for the study and the cleanup of air pollution. But there was no comprehensive federal response to address air pollution until Congress passed a much stronger Clean Air Act in 1970. That same year Congress created the EPA and gave it the primary role in carrying out the law. Since 1970, EPA has been responsible for a variety of Clean Air Act programs to reduce air pollution nationwide.  In 1990, Congress dramatically revised and expanded the Clean Air Act, providing EPA even broader authority to implement and enforce regulations reducing air pollutant emissions. The 1990 Amendments also placed an increased emphasis on more cost-effective approaches to reduce air pollution.  **Details…**  **The Air Pollution Control Act of 1955**  ·         First federal air pollution legislation  ·         Funded research for scope and sources of air pollution  **Clean Air Act of 1963**  ·         Authorized the development of a national program to address air pollution related environmental problems  ·         Authorized research into techniques to minimize air pollution  **Air Quality Act of 1967**  ·         Authorized enforcement procedures for air pollution problems involving interstate transport of pollutants  ·         Authorized expanded research activities  **Clean Air Act 1970**  ·         Authorized the establishment of National Ambient Air Quality Standards  ·         Established requirements for State Implementation Plans to achieve the National Ambient Air Quality Standards  ·         Authorized the establishment of New Source Performance Standards for new and modified stationary sources  ·         Authorized the establishment of National Emission Standards for Hazardous Air Pollutants  ·         Increased enforcement authority  ·         Authorized requirements for control of motor vehicle emissions  **1977 Amendments to the Clean Air Act of 1970**  ·         Authorized provisions related to the Prevention of Significant Deterioration  ·         Authorized provisions relating to areas which are non-attainment with respect to the National Ambient Air Quality Standards  **1990 Amendments to the Clean Air Act of 1970**  ·         Authorized programs for Acid Deposition Control  ·         Authorized a program to control 189 toxic pollutants, including those previously regulated by the National Emission Standards for Hazardous Air Pollutants  ·         Established permit program requirements  ·         Expanded and modified provisions concerning the attainment of National Ambient Air Quality Standards  ·         Expanded and modified enforcement authority  ·         Established a program to phase out the use of chemicals that deplete the ozone layer.  **EPA’s Role**  Under the Clean Air Act, EPA sets limits on certain air pollutants, including setting limits on how much can be in the air anywhere in the United States. This helps to ensure basic health and environmental protection from air pollution for all Americans. The Clean Air Act also gives EPA the authority to limit emissions of air pollutants coming from sources like chemical plants, utilities, and steel mills. Individual states or tribes may have stronger air pollution laws, but they may not have weaker pollution limits than those set by EPA. EPA must approve state, tribal, and local agency plans for reducing air pollution. If a plan does not meet the necessary requirements, EPA can issue sanctions against the state and, if necessary, take over enforcing the Clean Air Act in that area. EPA assists state, tribal, and local agencies by providing research, expert studies, engineering designs, and funding to support clean air progress. Since 1970, Congress and the EPA have provided several billion dollars to the states, local agencies, and tribal nations to accomplish this.  **State and Local Governments’ Role**  It makes sense for state and local air pollution agencies to take the lead in carrying out the Clean Air Act. They are able to develop solutions for pollution problems that require special understanding of local industries, geography, housing, and travel patterns, as well as other factors. State, local, and tribal governments also monitor air quality, inspect facilities under their jurisdictions and enforce Clean Air Act regulations. States have to develop ***State Implementation Plans (SIPs)*** that outline how each state will control air pollution under the Clean Air Act. A SIP is a collection of the regulations, programs and policies that a state will use to clean up polluted areas. The states must involve the public and industries through hearings and opportunities to comment on the development of each state plan.  **Tribal Nations’ Role**  In its 1990 revision of the Clean Air Act, Congress recognized that Indian Tribes have the authority to implement air pollution control programs. EPA’s Tribal Authority Rule gives Tribes the ability to develop air quality management programs, write rules to reduce air pollution and implement and enforce their rules in Indian Country. While state and local agencies are responsible for all Clean Air Act requirements, Tribes may develop and implement only those parts of the Clean Air Act that are appropriate for their lands.  **Cleaning Up Commonly Found Air Pollutants**  Six criteria air pollutants are found all over the United States. They include particle pollution, ground-level ozone, carbon monoxide, sulfur dioxide, nitrogen dioxide, and lead. These pollutants can harm your health and the environment, and cause property damage.  EPA calls these pollutants ***"criteria" air pollutants*** because it regulates them by developing human health based and/or environmentally-based criteria (science-based guidelines) for setting permissible levels. The set of limits based on human health is called ***primary standards***. Another set of limits intended to prevent environmental and property damage is called ***secondary standards***.  A geographic area with air quality that is cleaner than the primary standard is called an ***"attainment" area***; areas that do not meet the primary standard are called ***"nonattainment" areas***.  **Criteria Air Pollutants**  **Ozone -** Ground level or "bad" ozone is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major sources of NOx and VOC. Breathing ozone can trigger a variety of health problems, particularly for children, the elderly, and people of all ages who have lung diseases such as asthma. Ground level ozone can also have harmful effects on sensitive vegetation and ecosystems.  **Particle Pollution -** Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Particles less than 10 micrometers in diameter pose the greatest problems, because they can get deep into your lungs, and some may even get into your bloodstream.  Fine particles (PM2.5) are the main cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas.  **Carbon Monoxide**  Breathing air with a high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain.  At very high levels, which are possible indoors or in other enclosed environments, CO can cause dizziness, confusion, unconsciousness and death.  Very high levels of CO are not likely to occur outdoors. However, when CO levels are elevated outdoors, they can be of particular concern for people with some types of heart disease. These people already have a reduced ability for getting oxygenated blood to their hearts in situations where the heart needs more oxygen than usual. They are especially vulnerable to the effects of CO when exercising or under increased stress. In these situations, short-term exposure to elevated CO may result in reduced oxygen to the heart accompanied by chest pain also known as angina.  **Lead**  Once taken into the body, lead distributes throughout the body in the blood and is accumulated in the bones.  Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system.  Lead exposure also affects the oxygen carrying capacity of the blood.  The lead effects most commonly encountered in current populations are neurological effects in children and cardiovascular effects (e.g., high blood pressure and heart disease) in adults.  Infants and young children are especially sensitive to even low levels of lead, which may contribute to behavioral problems, learning deficits and lowered IQ.  **Sulfur Dioxides**  Short-term exposures to SO2 can harm the human respiratory system and make breathing difficult. Children, the elderly, and those who suffer from asthma are particularly sensitive to effects of SO2.  SO2 emissions that lead to high concentrations of SO2 in the air generally also lead to the formation of other sulfur oxides (SOx). SOx can react with other compounds in the atmosphere to form small particles. These particles contribute to particulate matter (PM) pollution: particles may penetrate deeply into sensitive parts of the lungs and cause additional health problems.  **Nitrous Dioxides**  Breathing air with a high concentration of NO2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections. People with asthma, as well as children and the elderly are generally at greater risk for the health effects of NO2.  NO2 along with other nitric oxide (NO) reacts with other chemicals in the air to form both particulate matter and ozone. Both of these are also harmful when inhaled due to effects on the respiratory system.  **Ways to Reduce Air Pollution**  **Conserve energy**  ■Turn off appliances and lights when you leave the room. ■ Recycle paper, plastic, glass bottles, cardboard, and aluminum cans. (This conserves energy and reduces production emissions.) ■Keep woodstoves and fireplaces well maintained. You should also consider replacing old wood stoves with EPA-certified models. ■Plant deciduous trees in locations around your home to provide shade in the summer, but to allow light in the winter. ■Buy green electricity–produced by low–or even zero-pollution facilities. ■Connect your outdoor lights to a timer or use solar lighting. ■Wash clothes with warm or cold water instead of hot. ■Lower the thermostat on your water heater to 120 degrees F. ■Use low-VOC or water-based paints, stains, Test your home for radon. Choose not to smoke in your home, especially if you have children. If you or your visitors must smoke, then smoke outside. ■ Choose efficient, low-polluting models of vehicles. ■ Choose products that have less packaging and are reusable. ■ Shop with a canvas bag instead of using paper and plastic bags. ■ Buy rechargeable batteries for devices used frequently.  **Drive Wise**  ■Plan your trips. Save gasoline and reduce air pollution. ■ Keep tires properly inflated and aligned. ■ In the summertime, fill gas tank during cooler evening hours to cut down on evaporation. ■Avoid spilling gas and don't “top off” the tank. Replace gas tank cap tightly. ■ Avoid waiting in long drive-thru lines, for example, at fast-food restaurants or banks. Park your car and go in. ■ When possible, use public transportation, walk, or ride a bike. ■ Get regular engine tune ups and car maintenance checks (especially for the spark plugs). ■ Use an energy-conserving (EC) grade motor oil. ■ Ask your employer to consider flexible work schedules or telecommuting. ■ Report smoking vehicles to your local air agency. ■ Join a carpool or vanpool to get to work.  **For Your Health**  ■ Check daily air quality forecasts, which tell how clean or polluted your air is, and the associated health concerns. ■ Remove indoor asthma triggers from your home and avoid outdoor triggers in order to effectively control your asthma ■ Minimize your sun exposure. Wear sun block and UV protection sunglasses. | | | | |
| **Temperature Inversion** | | Source Material taken from http://www.wrh.noaa.gov/slc/climate/TemperatureInversions.php | | |
| **LS2.C: Ecosystem Dynamics, Functioning, and Resilience:** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations.  Note that thermal inversions create a change in ecosystem – air pollution levels in the local area are raised greatly – the most sensitive populations (elderly, very young, health compromised) are typically affected first and most severely.  **Temperature Inversion**  On most days, the temperature of air in the atmosphere is cooler the higher up in altitude you go. This is because most of the suns energy is converted to sensible heat at the ground, which in turn warms the air at the surface. The warm air rises in the atmosphere, where it expands and cools. Sometimes, however, the temperature of air increases with height. The situation of having warm air on top of cooler air is referred to as a temperature inversion, because the temperature profile of the atmosphere is "inverted" from its usual state. There are two types of temperature inversions: surface inversions that occur near the Earth's surface, and aloft inversions that occur above the ground. Surface inversions are the most important in the study of air quality.    **How do surface temperature inversions form?**  The most common manner in which surface inversions form is through the cooling of the air near the ground at night. Once the sun goes down, the ground loses heat very quickly, and this cools the air that is in contact with the ground. However, since air is a very poor conductor of heat, the air just above the surface remains warm. Conditions that favor the development of a strong surface inversion are calm winds, clear skies, and long nights. Calm winds prevent warmer air above the surface from mixing down to the ground, and clear skies increase the rate of cooling at the Earth's surface. Long nights allow for the cooling of the ground to continue over a longer period of time, resulting in a greater temperature decrease at the surface. Since the nights in the wintertime are much longer than nights during the summertime, surface inversions are stronger and more common during the winter months. A strong inversion implies a substantial temperature difference exists between the cool surface air and the warmer air aloft. During the daylight hours, surface inversions normally weaken and disappear as the sun warms the Earth's surface. However, under certain meteorological conditions, such as strong high pressure over the area, these inversions can persist as long as several days. In addition, local topographical features can enhance the formation of inversions, especially in valley locations.  **How do inversions impact air quality?**  Surface temperature inversions play a major role in air quality, especially during the winter when these inversions are the strongest. The warm air above cooler air acts like a lid, suppressing vertical mixing and trapping the cooler air at the surface. As pollutants from vehicles, fireplaces, and industry are emitted into the air, the inversion traps these pollutants near the ground, leading to poor air quality. The strength and duration of the inversion will control AQI levels near the ground. A strong inversion will confine pollutants to a shallow vertical layer, leading to high AQI levels, while a weak inversion will lead to lower AQI levels. A large contributor to poor air quality during the winter is residential wood burning. Wood smoke contains much higher amounts of particulate pollution than smoke from oil- or gas-fired furnaces. In some areas of the country, local governments issue burn bans to curtail the use of woodstoves and fireplaces under certain weather and pollution conditions during the winter. | | | | |
| **Demonstration Project**  **Inversion in a Cup** | | | **Materials taken from Source:** <https://www.deq.idaho.gov/media/570177-inversion_in_cup_lp.pdf> | |
| **Cross Cutting Idea: Stability and Change** – Small changes (temperature) in one part of a system might cause large changes (air pollutants unable to disperse) in another part.  Discuss how the warm air at a higher elevation than cold air can cause a thermal inversion to occur. This change in the system can cause a “trap” where pollutants are not dispersed, and people, animals, and the environment can be exposed to higher than normal pollutant levels.  **Engaging in Argument from Evidence:** Use an oral argument supported by empirical evidence (shown in demonstration) to support or refute the explanation for the phenomenon.  **Grade Level:** Middle School  **Time Required:** Approximately 30 minutes (time will vary depending on discussion time)  **Objective:** To observe how temperature inversions are formed and discuss how inversions influence air pollution levels.  **Focus:** Air quality, inversions. Students create a temperature inversion, observe how the layer of cold becomes trapped, and discuss how pollutants can become trapped with that cold.  **Materials:** (per demonstration)  3 cups tap water, divided\*  1/8 cup salt (or a little less)\*  2 clear, 16-oz plastic cups (glass jars and glass bowls also work, as do other sizes of containers\*)  1/8 (or 1/4)-cup measuring cup\*  2-cup measuring cup\*  Blue food coloring (in a container that allows you to meter out drop by drop)  Funnel  Rubber tubing (about 1-foot long; appropriate width to fit snugly on end of funnel)  Spoon  **Background:**  Typically, warm air rises and cold air sinks, causing the air around us to mix and move. This process is called “convection.” In addition, winds continually move the air and disperse (scatter) pollution released into the air. However, sometimes the air does not mix and move, and a temperature (or “thermal”) inversion may occur.  A temperature inversion occurs when a layer of warm air settles on top of a layer of cold air, and the cold air ends up trapped underneath. In this situation, the layers of air do not move, the air does not mix, and pollution from cars, industry, fires, and other sources becomes trapped in the colder layer close to the earth’s surface. If an inversion persists for several days, this buildup of pollution can become significant.  Temperature inversions are natural occurrences that occur year-round, but are of major concern in the winter. They are neither caused by, nor the cause of, air pollution. However, an inversion can trap air pollution near the ground, thereby increasing the potential for higher concentrations of air pollution in a specific area. Because of this, temperature inversions and air pollution issues are often linked.  Inversions can develop or intensify on clear winter nights when the earth’s surface radiates (gives off) heat rapidly, which can cause the ground, and the air directly above it, to be cooler than the air at higher altitudes. Inversions can also form at night in valleys, when gravity pulls cold, dense air downhill into the valleys. The air in the valley bottoms is then colder than the air above. As stated above, inversions can trap air pollution near the earth’s surface. Pollution near the ground increases with the duration of the inversion, as more and more pollutants are released into the environment, and become concentrated in one location.  Two pollutants that commonly become trapped near the ground during inversions are carbon monoxide (CO) and particulate matter (“particulates” or PM). Both CO and PM can adversely impact public health and visibility and are regulated air pollutants under the National Ambient Air Quality Standards (NAAQS). Carbon monoxide forms when the carbon in fuels does not completely burn. Carbon monoxide concentrations typically are highest during cold weather because cold temperatures make combustion less complete. When this is coupled with inversion conditions, CO levels near the earth’s surface can increase. Particulate matter is made of small particles in the air including dust, dirt, soot, smoke, and liquid droplets. PM comes from exhaust from vehicles (especially diesel vehicles), such as cars, trucks, and buses, and from wood smoke, road dust, brake and tire wear, factories, construction sites, agricultural fields, and more. These pollutants can become trapped near the ground under inversion conditions.  Unfortunately, the cold air temperatures that are part of an inversion also lead to increased use of fireplaces and wood-burning stoves, as people are heating their homes against the chill. The smoke from these fires, and the particulates it generates, can quickly lead to high levels of particulate pollution trapped near the ground.  Air quality is reported using the Air Quality Index (AQI). The AQI indicates how clean or polluted the air is in a particular area and identifies potential health impacts. In some instances, DEQ forecasts the following day’s AQI so people who are especially sensitive to pollution can appropriately plan outdoor activities. As pollutants become trapped near the ground during an inversion, the AQI generally rises, indicating decreasing air quality and an increased chance of health impacts. | | | | |
| **Demonstration Procedure:**  **Step 1.** Pick a nearby high-altitude landmark that most of your students are familiar with (e.g., a nearby ski resort, town, or mountain peak that is significantly higher in elevation than your school). Ask for a show of hands of who has been there.  **Step 2.** Ask students what differences they notice in weather between the landmark and their town. *Answers may include: colder, more snow, windier (all referring to the landmark). If students don’t say “colder,” steer them in that direction.*  **Step 3.** Ask the students what this tells us about temperature patterns in general. *It gets colder as elevation increases.*  **Step 4.** Discuss with students how air typically moves, heats, and cools. *Generally, warm air rises. As it rises, it cools (because it gets higher), which makes it heavier, so it sinks, then warms, then rises again. This process is called “convection.” Cold air is denser than warm air, which makes it heavier, which is why it “sinks.”*  **Step 5.** Ask students if they have heard the terms, “invert,” “inverted,” or “inversion” (in any context). Ask what they mean. *Look for answers that generally mean “upside down.”*  **Step 6.** Ask students if they have heard the term “inversion” related to weather. If any have, ask what it means. *An inversion is a reversal in the normal temperature layers. A layer of warm air settles on top of a layer of cold air, and the cold air ends up trapped underneath. The end result is that areas of lower elevation are colder than areas of higher elevation; the opposite of normal temperature regimes. That is, the temperatures are “upside down.”*  **Step 7.** Tell students you are going to build an inversion out of water. You are using water because it is easier to see than air. **As you do this demonstration, get one or two student volunteers to do or help with the following steps.**  **Step 8.** Place the plastic cups on a stable table or desk where everyone in the group can see them. If you are doing as a demonstration, allow students to position themselves around the table/desk so that everyone has a good view, but keep them back far enough that the table/desk doesn’t get jostled.  **Step 9.** Measure 1.5 cups of tap water\* using the 2-cup measuring cup. Pour into one of the plastic cups. Label this cup “1.”  **Step 10.** Measure ¾ cup of tap water\* in the 2-cup measuring cup and pour into the second cup. Label this cup “2.”  **Step 11.** Measure a second ¾ cup\* of tap water in the 2-cup measuring cup and add 1/8-cup\* (or slightly less) salt. Stir vigorously with a spoon until the salt is completely (or nearly completely) dissolved.  **Step 12.** Fit one end of the tubing over the end of the funnel. Lower the other end of the tubing into cup #2 so that the end of the tubing rests on the bottom of the cup. Have one student hold on to the tubing against the side of the cup so it stays in place. (This is important, as you don’t want to agitate the water and you want the salt water you add to be added to the bottom of the cup.)  **Step 13.** Carefully pour the ¾ cup of salt water into the funnel so that it comes out of the tube at the bottom of the cup. It is OK if some bubbles come out of the tube, but try to keep agitation to a minimum.  **Step 14.** Gently remove the tubing from the cup, taking care not to disturb the water.  **Step 15.** Review what you have done so far and discuss what the water in the cups represents. The water in cup #1 represents normal weather conditions. The air (water) is free to mix and move. This is the “control.” The water in cup #2 represents an inversion. The first water you put in cup #2 represents warm air. The second water (salt water) you put in cup #2 represents cold air. Cold air is denser/heavier than warm air. The salt makes the second cup of water denser/heavier than the first, so simulates cold air. You now have an “inversion” in a cup (salty, heavy water [representing cold, heavy air] is trapped under un-salty, lighter water [representing warmer, lighter air]).  **Point out that, at this point, just as in real life, the different layers of air (water) are not visibly different** (unless or until pollution gets trapped). In real life, it is the trapped pollution that makes the different layers of air visible during an inversion. The air itself (if not polluted) all looks the same.  **Step 16.** Tell your students that you will now add food coloring to see what happens. Slowly, allowing 1 to 2 seconds between drops, drop 3 drops of food coloring into the water in cup #1. The food coloring should slowly mix with the water to make a more-or-less uniform color.  **Step 17.** Slowly, allowing 1 to 2 seconds between drops, drop 3 drops of food coloring into the water in cup #2. Take care to not disturb the water in the cup (don’t bump the cup, table, etc.). The food coloring should stay in the top (unsalted, representing warm, light air) layer of water and will likely make a “swirl” pattern.  **Step 18.** Using a spoon, gently agitate the top ½-inch of the water in the top of cup #2. DO NOT dip the spoon in to the bottom of the cup. The layers should appear more obvious, and you may be able to see the boundary between layers as the water undulates. You may want to agitate more than once (getting a little more aggressive each time) to accentuate the layers. However, be sure to keep the spoon in the top ½-inch of water to keep from mixing the entire cup.  **Step 19.** Compare and contrast what you see in the two cups. Students should easily see the clear water (the “clear” water may be a little “foggy” because of the salt) on the bottom (represents the cold, trapped air) and the colored water on top (represents the warm air) in cup #2. Discuss how the warm (now colored) “air” traps the cold, heavy “air” beneath it and how pollution gets trapped with that cold air. (**Do not confuse the colored upper [warm] layer as being polluted. The food coloring does NOT represent pollution – it simply allows you to see the two layers of air.**)  **Step 20.** Gently swirl the water in the cup (or stir with a spoon) to simulate wind. Note how the “wind” breaks up the “inversion” (mixes the “air”) so that all the water mixes and becomes homogenous (the same). Precipitation (e.g., rain or snow) can break up an inversion as well. (Some students may want to pour additional water into the cup to simulate rain instead of swirling or stirring the water to simulate wind.)  **Step 21.** Teacher/Leader. Lead a class discussion using Questions for Discussion, below. | | | | |
| **Questions for Discussion**  **1. How are temperature inversions formed?**  *Inversions can develop or intensify on clear winter nights when the earth’s surface radiates (gives off) heat rapidly, which can cause the ground, and the air directly above it, to be cooler than the air at higher altitudes. Inversions can also form at night in valleys, when gravity pulls cold, dense air downhill into the valleys. The air in the valley bottoms is then colder than the air above.*  **2. Temperature inversions are directly related to the temperature of the air. In our experiment, all the water we used was the same temperature. How/why did it work?**  *Cold air/water is denser (and therefore heavier) than warm air/water. Water saturated with salt is denser (heavier) than un-salty water (this is also why you float better in the ocean than in a lake). So the dense, heavy salt water was used to represent the dense, heavy cold air.*  **3. In an experiment, what is the “control”? In our experiment, which cup represented the “control”?**  *A “control” is a standard in a scientific experiment that you used to compare other things to. It is the “thing” that is not manipulated or changed. Cup #1 (the cup that did not have any salt water added) was the “control” in this experiment because it was just plain water.*  **4. How does what we did relate to “real life”?**  *In “real life,” inversions trap air pollution close to the ground, where we breathe it. Inversions and their effect on air pollution are especially problematic in the winter: inversions most often occur in the winter, people are most likely to be burning wood in stoves and fireplaces in the winter and the pollution from smoke (particulates) gets trapped by the inversion, and engines don’t burn as efficiently when it is cold, which creates more carbon monoxide, which also gets trapped in an inversion.*  **5. Does our community experience inversions? How can we find out if an inversion is occurring? How can we find out about air quality in our community?**  *Local newscasts/weather reports on the TV or radio will report if an inversion is occurring. Checking weather sites on the Internet will also provide clues if there is an inversion (that is, the site may not specifically say there is an inversion, but if you check the air temperature in your community and for a nearby higher elevation area and the higher elevation is warmer, then your community may be experiencing an inversion).*  **6. Why should we care about air pollution?**  *It hurts the environment, is unhealthy, blocks views, stinks, can cause economic issues if air quality doesn’t meet national standards. Point out that many of these issues exist even in places with relatively clean air.*  **7. Do inversions cause air pollution?**  *No. Temperature inversions are natural occurrences. They are neither caused by, nor the cause of, air*  *pollution. However, an inversion can trap air pollution near the ground, thereby increasing the concentration of air pollution in a specific area. Because of this, temperature inversions and air pollution issues are often linked.*  **8. What does cause air pollution? What are the biggest causes of air pollution in our town?**  *Vehicle exhaust (especially from diesel engines), industry, fires (wildfires, agricultural burning,*  *fireplaces/wood stoves), blowing dust, volcanoes, gas-powered lawn tools (e.g., lawn mowers), etc. (These are general causes; the biggest polluters in your town will vary. Typically, vehicles are the biggest polluters in urban areas. Wood smoke can be a large polluter in rural areas.)*  **9. How can we prevent inversions from happening?**  *We can’t. They are a natural weather phenomenon and have been occurring since long before humans altered the environment. However, human activity (pollution) can affect the duration and severity of some inversions. What we can do is take action to reduce air pollution so that when an inversion occurs, there is less pollution in the air to become trapped in the inversion.* | | | | |
| **Teacher Prep** |  |  | | |
|  | **Advanced Preparation Steps &**  **Duration** | 1. Read and consider associated background material, demonstration procedures, and questions for discussion. (1 hour) 2. Review EPA video clip (15 minutes) 3. Review Air Pollution PowerPoint (15 minutes) 4. Assemble Demonstration Materials & Practice Demonstration (3 hours) | | |
| **Needed Materials** |  |  | | |
|  |  | EPA Video Clip - Air Science 40 - Celebrating Four Decades of Innovative Research <https://www.youtube.com/watch?v=C-UGNZRgu84> (13:02 minutes)   1. Materials: (per demonstration)   3 cups tap water, divided\*  1/8 cup salt (or a little less)\*  2 clear, 16-oz plastic cups (glass jars and glass bowls also work, as do other sizes of containers\*)  1/8 (or 1/4)-cup measuring cup\*  2-cup measuring cup\*  Blue food coloring (in a container that allows you to meter out drop by drop)  Funnel  Rubber tubing (about 1-foot long; appropriate width to fit snugly on end of funnel)  Spoon   1. Air Pollution PowerPoint 2. Internet Connection | | |
|  | **Duration of activities** | 50 minutes | | |
|  | **Safety notes** | Always handle materials with care. Do not drink or ingest materials. | | |
| **Procedures for instruction** |  |  | | |
|  |  | Introduce the class to the idea of air quality. | | ~2 minutes |
|  |  | Show the associated film Air Science 40 - Celebrating Four Decades of Innovative Research | | ~13 minutes  (YouTube Film) |
|  |  | Introduce the Clean Air Act, Criteria Pollutants, and the science of thermal inversions. | | ~10 minutes  (PowerPoint) |
|  |  | Thermal Inversion Demonstration | | ~15 minutes  (Class Demonstration) |
|  |  | Discussion | | ~10 minutes |
| **Student Materials** |  |  | | |
|  | Background Informational Sheet | Reading assignment prior to the demonstration day. | | |
|  | Vocabulary List | Available for clarification of terminology as students read their Background Informational Sheet and Demonstration Procedure | | |

|  |  |
| --- | --- |
| **Student Background Information Sheet – Air Pollution** | |
| **Source:** The Plain English Guide to the Clean Air Act https://www.epa.gov/sites/production/files/2015-08/documents/peg.pdf  **Background**  Air pollution can damage trees, crops, other plants, natural environment, air pollution also damages reduces how far you can see in national parks and cities, it even interferes with aviation.  In 1970, Congress created the Environmental Protection Agency (EPA) and passed the Clean Air Act, giving the federal government authority to clean up air pollution in this country. Since then, EPA and states, tribes, local governments, industry, and environmental groups have worked to establish a variety of programs to reduce air pollution levels across America.  **Air Pollution and Your Health**  Breathing polluted air can make your eyes and nose burn. It can irritate your throat and make breathing difficult. In fact, pollutants like tiny airborne particles and ground-level ozone can trigger respiratory problems, especially for people with asthma. Asthma sufferers can be severely affected by air pollution. It can also aggravate health problems for the elderly and others with heart or respiratory diseases. Other pollutants make their way up into the upper atmosphere, causing a thinning of the protective ozone layer. This has led to changes in the environment and dramatic increases in skin cancers and cataracts (eye damage).  **Air Pollution and the Environment**  Air pollution isn’t just a threat to our health, it also damages our environment. Toxic air pollutants and the chemicals that form acid rain and ground-level ozone can damage trees, crops, wildlife, lakes and other bodies of water. Those pollutants can also harm fish and other aquatic life.  **Air Pollution and the Economy**  The health, environmental, and economic impacts of air pollution are significant. Each day, air pollution causes thousands of illnesses leading to lost days at work and school. Air pollution also reduces agricultural crop and commercial forest yields by billions of dollars each year.  **Progress**  By reducing air pollution, the Clean Air Act has led to significant improvements in human health and the environment in the U.S.  **History of the Clean Air Act**  The original Clean Air Act of 1963 established funding for the study and the cleanup of air pollution. But there was no comprehensive federal response to address air pollution until Congress passed a much stronger Clean Air Act in 1970. That same year Congress created the EPA and gave it the primary role in carrying out the law. Since 1970 the EPA has been responsible for a variety of Clean Air Act programs to reduce air pollution nationwide.  In 1990, Congress dramatically revised and expanded the Clean Air Act, providing EPA even broader authority to implement and enforce regulations reducing air pollutant emissions. The 1990 Amendments also placed an increased emphasis on more cost-effective approaches to reduce air pollution.  **EPA’s Role**  Under the Clean Air Act, EPA sets limits on certain air pollutants, including setting limits on how much can be in the air anywhere in the United States. This helps to ensure basic health and environmental protection from air pollution for all Americans. The Clean Air Act also gives EPA the authority to limit emissions of air pollutants coming from sources like chemical plants, utilities, and steel mills. Individual states or tribes may have stronger air pollution laws, but they may not have weaker pollution limits than those set by EPA. EPA must approve state, tribal, and local agency plans for reducing air pollution. If a plan does not meet the necessary requirements, EPA can issue sanctions against the state and, if necessary, take over enforcing the Clean Air Act in that area.  **State and Local Governments’ Role**  It makes sense for state and local air pollution agencies to take the lead in carrying out the Clean Air Act. They are able to develop solutions for pollution problems that require special understanding of local industries, geography, housing, and travel patterns, as well as other factors. States have to develop ***State Implementation Plans (SIPs)*** that outline how each state will control air pollution under the Clean Air Act. A SIP is a collection of the regulations, programs and policies that a state will use to clean up polluted areas.  **Tribal Nations’ Role**  In its 1990 revision of the Clean Air Act, Congress recognized that Indian Tribes have the authority to implement air pollution control programs. EPA’s Tribal Authority Rule gives Tribes the ability to develop air quality management programs, write rules to reduce air pollution and implement and enforce their rules in Indian Country. While state and local agencies are responsible for all Clean Air Act requirements, Tribes may develop and implement only those parts of the Clean Air Act that are appropriate for their lands.  **Cleaning Up Commonly Found Air Pollutants**  Six criteria air pollutants are found all over the United States. They include particle pollution, ground-level ozone, carbon monoxide, sulfur oxides, nitrogen oxides, and lead. These pollutants can harm your health and the environment, and cause property damage.  The set of limits based on human health is called ***primary standards***. Another set of limits intended to prevent environmental and property damage is called ***secondary standards***.  A geographic area with air quality that is cleaner than the primary standard is called an ***"attainment" area***; areas that do not meet the primary standard are called ***"nonattainment" areas***.  **Criteria Air Pollutants**  **Ozone -** Ground level or "bad" ozone is not emitted directly into the air, but is created by chemical reactions between oxides of nitrogen (NOx) and volatile organic compounds (VOC) in the presence of sunlight. Emissions from industrial facilities and electric utilities, motor vehicle exhaust, gasoline vapors, and chemical solvents are some of the major sources of NOx and VOC. Breathing ozone can trigger a variety of health problems, particularly for children, the elderly, and people of all ages who have lung diseases such as asthma. Ground level ozone can also have harmful effects on sensitive vegetation and ecosystems.  **Particle Pollution -** Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems.  Fine particles are the main cause of reduced visibility (haze) in parts of the United States, including many of our treasured national parks and wilderness areas.  **Carbon Monoxide**  Breathing air with a high concentration of CO reduces the amount of oxygen that can be transported in the blood stream to critical organs like the heart and brain.  At very high levels, which are possible indoors or in other enclosed environments, CO can cause dizziness, confusion, unconsciousness and death.  **Lead**  Once taken into the body, lead distributes throughout the body in the blood and is accumulated in the bones.  Depending on the level of exposure, lead can adversely affect the nervous system, kidney function, immune system, reproductive and developmental systems and the cardiovascular system.  Lead exposure also affects the oxygen carrying capacity of the blood.  **Sulfur Dioxide**  Short-term exposures to SO2 can harm the human respiratory system and make breathing difficult. Children, the elderly, and those who suffer from asthma are particularly sensitive to effects of SO2.  **Nitrous Oxide**  Breathing air with a high concentration of NO2 can irritate airways in the human respiratory system. Such exposures over short periods can aggravate respiratory diseases, particularly asthma, leading to respiratory symptoms (such as coughing, wheezing or difficulty breathing), hospital admissions and visits to emergency rooms. Longer exposures to elevated concentrations of NO2 may contribute to the development of asthma and potentially increase susceptibility to respiratory infections.  **Ways to Reduce Air Pollution**  **Conserve energy**  ■Turn off appliances and lights when you leave the room. ■ Recycle paper, plastic, glass bottles, cardboard, and aluminum cans. (This conserves energy and reduces production emissions.) ■Wash clothes with warm or cold water instead of hot. ■ Choose efficient, low-polluting models of vehicles. ■ Choose products that have less packaging and are reusable. ■ Shop with a canvas bag instead of using paper and plastic bags. ■ Buy rechargeable batteries for devices used frequently.  **Drive Wise**  ■Plan your trips. Save gasoline and reduce air pollution. ■ When possible, use public transportation, walk, or ride a bike. ■ Ask your employer to consider flexible work schedules or telecommuting. ■ Join a carpool or vanpool to get to work.  **For Your Health**  ■ Check daily air quality forecasts, which tell how clean or polluted your air is, and the associated health concerns. ■ Remove indoor asthma triggers from your home and avoid outdoor triggers in order to effectively control your asthma ■ Minimize your sun exposure. Wear sun block and UV protection sunglasses.  **Source:** Material taken from http://www.wrh.noaa.gov/slc/climate/TemperatureInversions.php  **Thermal Inversions**  The situation of having warm air on top of cooler air is referred to as a temperature inversion, because the temperature profile of the atmosphere is "inverted" from its usual state. There are two types of temperature inversions: surface inversions that occur near the Earth's surface, and aloft inversions that occur above the ground. Surface inversions are the most important in the study of air quality.  **How do surface temperature inversions form?**  The most common manner in which surface inversions form is through the cooling of the air near the ground at night. Once the sun goes down, the ground loses heat very quickly, and this cools the air that is in contact with the ground. However, since air is a very poor conductor of heat, the air just above the surface remains warm. Conditions that favor the development of a strong surface inversion are calm winds, clear skies, and long nights. Calm winds prevent warmer air above the surface from mixing down to the ground, and clear skies increase the rate of cooling at the Earth's surface. Long nights allow for the cooling of the ground to continue over a longer period of time, resulting in a greater temperature decrease at the surface. Since the nights in the wintertime are much longer than nights during the summertime, surface inversions are stronger and more common during the winter months.  **How do inversions impact air quality?**  Surface temperature inversions play a major role in air quality, especially during the winter when these inversions are the strongest. The warm air above cooler air acts like a lid, suppressing vertical mixing and trapping the cooler air at the surface. As pollutants from vehicles, fireplaces, and industry are emitted into the air, the inversion traps these pollutants near the ground, leading to poor air quality. | |
| **Student Vocabulary List– Air Pollution** | |
| **Air Quality Index (AQI)** | A guide for reporting daily air quality that indicates how clean or polluted the air is in a particular area and identifies potential health impacts. |
| **Attainment Area** | A geographic area with air quality that is cleaner than the primary standard. |
| **Carbon Monoxide - (CO)** | A colorless, odorless, poisonous gas and one of six “criteria pollutants” for which the U.S. Environmental Protection Agency (EPA) has established protective standards. |
| **Certified/Non-Certified Wood Stove** | A certified wood stove is any wood stove manufactured since 1988. Since this time, Certified wood stoves are cleaner and more efficient than a wood stove manufactured before 1988. |
| **Combustion** | The process of burning. |
| **Convection** | The vertical movement of heat within the atmosphere |
| **Emission** | The act or instance of discharging (emitting) something into the air, such as by an internal combustion engine (e.g., a vehicle). |
| **Emit** | To give off or discharge. |
| **Exhaust** | The fumes or gases released from an engine. |
| **Inversion (“Thermal” or “Temperature”)** | A reversal in the normal temperature layers. A layer of warm air settles on top of a layer of cold air, and the cold air ends up trapped underneath. |
| **Nonattainment Area** | Areas that do not meet the primary standard for air quality. |
| **Particulate Matter (“particulates” or PM)** | Small particles suspended in the air including dust, dirt, soot, smoke, and liquid droplets. |
| **Pollutant** | Any substance introduced into the environment that adversely affects the usefulness of a resource or the health of humans, animals, or ecosystems. |
| **Primary Standards** | The set limits for air quality based to protect human health. |
| **Secondary Standards** | The set of air pollution limits intended to prevent environmental and property damage. |

**Project Assessment**

**Project Title:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Instructor/School/Grade:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_/\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_/\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Instructor Contact Information:** \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

**Date assigned to your class:** \_\_\_\_\_\_\_\_\_\_\_\_ **# of Students Participating** \_\_\_\_\_\_\_\_\_\_\_\_\_

The following questions are intended to help us understand your feelings regarding the presentation and materials. Your sincerity in answering these questions is appreciated. Please feel free to use the space at the end of the form for any additional comments that you may have. *This form has been left in Microsoft Word format so that you may fill it in electronically. Please fill out the form completely and email your assessment to* [david.madore@maine.gov](mailto:david.madore@maine.gov).

**Ranking System**

1 ~ Excellent / Strongly agree

2 ~ Good – Above average / Moderately agree

3 ~ Average – ok / Neutral in agree or disagree

4 ~ Poor – below average / Moderately disagree

4 ~ Very poor – not acceptable / Strongly disagree

NA / not applicable

*Please continue on the second pagee…*

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **1** | **2** | **3** | **4** | **5** | **NA** | **Questions** |
|  |  |  |  |  |  | **Course Content** |
|  |  |  |  |  |  | 1. Value of course content to you. |
|  |  |  |  |  |  | 1. Importance of course content given your teaching topic. |
|  |  |  |  |  |  | 1. Overall rating of course content. |
|  |  |  |  |  |  | 1. Ease of implementing materials into daily lessons. |
|  |  |  |  |  |  | **Materials/Project** |
|  |  |  |  |  |  | 1. Movie (if applicable) was easy to present. |
|  |  |  |  |  |  | 1. Student worksheet was useful and easy to follow. |
|  |  |  |  |  |  | 1. Student project stimulated thinking & conversation. |
|  |  |  |  |  |  | 1. The project put ideas across effectively. |
|  |  |  |  |  |  | 1. Teacher materials were useful and easy to follow. |
|  |  |  |  |  |  | 1. The method of material presentation encouraged students feel free to ask questions, disagree, express ideas, etc. |
|  |  |  |  |  |  | **Self-Evaluation (Instructor)** |
|  |  |  |  |  |  | 1. What was your level of knowledge concerning this topic prior to this presentation? |
| **Please share any recommendations you feel would be helpful.** | | | | | | |

**Thank you for providing your feedback!**

Please email your assessment to david.madore@maine.gov.*e*