[redacted]

Course Learning Outcomes for Unit I

Upon completion of this unit, students should be able to:

1. Examine important air quality problems.
   1.1 Summarize the sources of specific air pollutants.

2. Assess processes impacting the physical distribution of environmental pollutants.
   2.1 Identify atmospheric processes that affect fate and transport of air pollutants.

7. Diagnose air quality concerns in the indoor environment.
   7.1 Analyze the regulatory efforts surrounding specific air pollutants.

Course/Unit Learning Outcomes	Learning Activity
1.1	Unit Lesson Chapter 1: The State of the Atmosphere Unit I Course Project Milestone One Assignment
2.1	Unit Lesson Chapter 2: The Physics of the Atmosphere Chapter 3: The Science of Air Pollution Unit I Assessment
7.1	Unit Lesson Chapter 1: The State of the Atmosphere Unit I Assessment

Reading Assignment

Chapter 1: The State of the Atmosphere, pp. 3–17

Chapter 2: The Physics of the Atmosphere

Chapter 3: The Science of Air Pollution

Unit Lesson

Perhaps the air at a remote cabin in the Adirondacks is medicine, but the air in Beijing is likely to cause you to develop health problems that require it. Everyone wants clean air, but what is clean? Air consists of a mixture of oxygen, nitrogen, argon, and carbon dioxide. If other gases or airborne particulates were considered contaminants at any level, then truly clean air would be almost impossible, even for a pre-industrial society. Therefore, we must define levels at which gases or particulate matter constitute pollution. This level depends on many factors, including the toxicity of the pollutant. Extremely toxic air pollutants can be harmful even at small concentrations, while less toxic air pollutants affect human health only at higher concentrations. For example, the National Ambient Air Quality Standard (NAAQS) for lead is 0.15 micrograms/cubic meter, and the NAAQS for particulate matter of less than 10 micrometers (PM_{10}) is 150 micrograms per cubic meter—1,000 times higher (U.S. Environmental Protection Agency [EPA], 2014b).

Not only does the toxicity of air pollutants vary, the nature of their sources varies as well. Sources of air pollution can be mobile or stationary. A single source may emit only a small amount of pollution, but the cumulative amount of pollution emitted from all the sources in an area can create extremely high levels of pollution. How far the pollutants travel from their sources depends on a variety of factors. Some factors are inherent to the pollutant particles themselves, such as particle size, shape, and chemical characteristics; other factors are external, such as wind direction, air turbulence, and other local weather phenomena.

The *transport mechanisms* and particle characteristics of a pollutant are only one aspect of the ultimate effects of air pollution. The nature of the receptors must be considered as well. If the area affected by a pollutant is an unpopulated area with a robust ecosystem that is minimally affected by the pollutant, then the cost of the pollution is not high. However, if a pollutant is affecting an area populated with sensitive individuals and ecosystems, there can be severe costs to human health and the environment. In making decisions about safe levels of pollution, transport mechanisms will tell us where the pollution is likely to land, but studying the *receptors* will tell us about the severity of the effects of that pollution.

People became aware of the effects of air pollution even before the Industrial Revolution. In fact, smoke and ash were such a problem in pre-industrial Great Britain that it prompted the first Public Health Act of 1848 (Vallero, 2014). After the Industrial Revolution, there were several air pollution disasters that made plain the devastating effects that unchecked air pollution could have. In the Meuse River Valley in Belgium, 60 people died and 6,000 people became ill over the course of three days due to a temperature inversion that trapped pollutants from the mills and factories in the narrow valley. In 1948 in Donora, PA, a similar event occurred that killed 20 people and sickened many others. The Great Smog of 1952 affected London for four days, resulting in the death of 4,000 more people than usual and an additional 8,000 fatalities in the weeks following the smog event. The London tragedy resulted in the passing of a Clean Air Act in England (Tracton, 2012). These events increased awareness of the link between air pollution and human health and paved the way for regulation.

In 1970, the *Clean Air Act* (CAA) was implemented to protect the public against excessive levels of certain airborne pollutants. The CAA sets limits on six *criteria pollutants*: lead, carbon monoxide, nitrogen dioxide, ozone, particulate matter, and sulfur dioxide. States that do not meet the standards set for these criteria pollutants are required to develop *State Implementation Plans (SIPs)* to achieve attainment. Hazardous air pollutants, acid rain, stratospheric ozone, and regional haze are also addressed by the CAA (EPA, 2013).

Although the CAA has improved air quality, there are still air contaminants that threaten human health and the environment. Particulate matter, which is released from power plants, industrial smokestacks, and automobiles is of particular concern. *Particulate matter (PM)* can be a mixture of pollutants, and the chemical characteristics of PM vary widely. PM also varies in size, from ultrafine to coarse (Vallero, 2014). $PM_{2.5}$, which is particulate matter less than 2.5 micrometers in diameter, has recently been linked with a higher risk of dementia. $PM_{2.5}$ can enter the brain through the nose, causing inflammation and promoting dementia (University of Southern California, 2017). Although $PM_{2.5}$ is regulated by the CAA, there are areas of the country that do not meet the NAAQS for $PM_{2.5}$, which is set at an annual mean (averaged over three years) of 12 micrograms/cubic meter for primary $PM_{2.5}$ (EPA, 2014b). However, the $PM_{2.5}$ levels in these nonattainment areas are still generally below those for cities such as Delhi and Beijing. $PM_{2.5}$ concentrations in Delhi averaged 132 micrograms per cubic meters for the past three years, and those in Beijing averaged 76 micrograms per cubic meters in 2016 ("70% cut," 2017; Stanway, 2017). Although most U.S. cities have lower $PM_{2.5}$ levels than Beijing or Delhi on average, there are still many days during which people in the United States. are breathing air that has well above the recommended level of 12 micrograms/cubic meter. For example, the Cache Valley area in Utah exceeded the NAAQS standard 17 days a year and exceeded the health impact limit 51 days per year during the last 15 years (Martin, Coulombe, & Brain, 2016).

Stratospheric ozone depletion is another air quality issue that the EPA is trying to address. Although ozone in the troposphere is a pollutant, ozone in the stratosphere protects us from ultraviolet radiation. Chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs) were identified as the main culprit in stratospheric ozone depletion, and under the Montreal Protocol, many countries have phased out production of CFCs. However, these chemicals persist for a long time in the atmosphere, and not all production of ozone-depleting substances has been phased out. Therefore, we are still dealing with the effects of stratospheric ozone depletion. If efforts are sustained, it is expected that the ozone hole will be gone by 2050 (EPA, 2015).

Efforts to address climate change have not been nearly as successful as those for stratospheric ozone depletion. According to a 2007 Supreme Court ruling, the EPA has the authority to regulate greenhouse gases under the CAA. In 2010, the EPA began regulating greenhouse gas emissions from new cars and light-duty vehicles. In addition, new or modified stationary sources are subject to new source review of greenhouse gas emissions. Under the Obama administration, the *Clean Power Plan* called for the establishment of New Source Performance Standards for fossil fuel power plants and refineries under the CAA; however, the legality of the plan was challenged by 28 states and various companies effectively halting its implementation (Center for Climate and Energy Solutions, n.d.; Davenport, 2017). In 2016, the U.S. Supreme Court voted to block the Clean Power Plan giving lower courts time to finish litigation and issue their decisions (Henry & Cama, 2016). In March 2017, President Trump signed the Energy Independence Executive Order directing all executive department agencies to review any existing regulations that hinder the use of domestically produced energy resources and rescinded several Obama administration energy and climate-related orders and reports. The EPA was specifically directed to review the Clean Power Plan for compliance with the Energy Independence Executive Order and authorized the agency to suspend, revise, or rescind the plan (Exec. Order No. 13,783, 2017).

Another aspect of air quality addressed by the CAA is acid deposition. *Nitrogen oxides (NO_x)* and *sulfur dioxide (SO_2)* are released by vehicles, industrial sources, and power plants. NO_x and SO_2 react with water and oxygen in the atmosphere to form nitric acid and sulfuric acid. The presence of nitric and sulfuric acid in precipitation decreases the pH of rain. The normal pH of rain is acidic, with a pH of about 5.6, whereas acid rain has a pH of between 4.2 and 4.4. Because the pH scale is exponential, this difference in pH means that acid rain is more than ten times more acidic than natural rain. As acid rain flows through soils, it leaches aluminum from the soil. This aluminum makes its way into freshwater bodies, increasing the amount of aluminum in the water. Many aquatic species are sensitive to the amount of aluminum in the water, and those species cannot survive in a more acidic environment. Acid rain also damages plants and trees, and it can corrode building materials. To combat acid rain, the 1990 amendments to the CAA established the *Acid Rain Program (ARP)*. This program set up a cap and trade system for SO_2 and called for a 2 million ton reduction in NO_x emissions from 1990 levels. The ARP has significantly reduced SO_2 and NO_x emissions, but ecosystems still have not fully recovered (EPA, 2014a).

We have come a long way from the air pollution disasters of the early 1900s, but air pollution still kills millions of people a year worldwide. In its *State of the Air 2016* report, the American Lung Association (2016) reported that although there has been improvement in the United States, the air is still unhealthy to breathe in many areas. These air quality problems can be solved, but many of them require an interdisciplinary approach. The transport of air pollutants involves physics, chemistry, and meteorology. The health effects of air pollutants are studied by toxicologists, and engineers design systems to limit the amount of pollutants emitted. As we have seen with the topic of climate change, even politicians get involved with air quality issues. Contributions from each of these fields of study will be necessary to build upon the progress we have made in making our air healthy to breathe.

References

American Lung Association. (2016). *State of the air 2016*. Retrieved from http://www.lung.org/assets/documents/healthy-air/state-of-the-air/sota-2016-full.pdf

Center for Climate and Energy Solutions. (n.d.). EPA greenhouse gas regulation FAQ. Retrieved from https://www.c2es.org/federal/executive/epa/greenhouse-gas-regulation-faq

Davenport, C. (2017, April 28). Court gives Trump small victory in push against clean power act. *The New York Times*. Retrieved from https://www.nytimes.com/2017/04/28/climate/clean-power-plan-global-warming.html

Exec. Order No. 13,783, 82 F.R. 16093 (2017).

Henry, D. & Cama, T. (2016, February 9). Supreme Court blocks Obama's climate rule for power plants. *The Hill*. Retrieved from http://thehill.com/policy/energy-environment/268843-supreme-court-blocks-obamas-climate-rule-for-power-plants

Martin, R., Coulombe, R., & Brain, R. (2016). *Utah air quality: PM$_{2.5}$.* Retrieved from http://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1783&context=extension_curall

70% cut in PM 2.5 levels needed. (2017, February 28). *The Times of India.* Retrieved from http://timesofindia.indiatimes.com/city/delhi/70-cut-in-pm2-5-levels-needed/articleshow/57381301.cms

Stanway, D. (2017, February 5). Beijing vows 30% cut in coal use in 2017 to fight crippling smog. *Reuters.* Retrieved from http://www.businessinsider.com/r-beijing-vows-30-percent-cut-in-coal-use-in-2017-to-fight-smog-2017-2

Tracton, S. (2012, December 20). The killer London smog event of December, 1952: A reminder of deadly smog events in U.S. *The Washington Post.* Retrieved from https://www.washingtonpost.com/blogs/capital-weather-gang/post/the-killer-london-smog-event-of-december-1952-a-reminder-of-deadly-smog-events-in-us/2012/12/19/452c66bc-498e-11e2-b6f0-e851e741d196_blog.html?utm_term=.1e59ba9eefaa

University of Southern California. (2017, January 31). Air pollution may lead to dementia in older women. *Science Daily.* Retrieved from https://www.sciencedaily.com/releases/2017/01/170131124137.htm

U.S. Environmental Protection Agency. (2013). Summary of the Clean Air Act: 42 U.S.C. §7401 et seq. (1970). Retrieved from https://www.epa.gov/laws-regulations/summary-clean-air-act

U.S. Environmental Protection Agency. (2014a). Acid Rain Program. Retrieved from https://www.epa.gov/airmarkets/acid-rain-program

U.S. Environmental Protection Agency. (2014b). NAAQS table. Retrieved from https://www.epa.gov/criteria-air-pollutants/naaqs-table

U.S. Environmental Protection Agency. (2015). Current state of the ozone layer. Retrieved from https://www.epa.gov/ozone-layer-protection/current-state-ozone-layer

Vallero, D. (2014). *Fundamentals of air pollution* (5th ed.). Waltham, MA: Academic Press.

Suggested Reading

In order to access the following resources, click the links below:

These videos provide further examples of air pollution, mitigation, and the effects of the atmosphere.

Allegro Productions (Producer). (1999). *The wind: Nature's action hero* [Video file]. Retrieved from https://libraryresources.columbiasouthern.edu/login?auth=CAS&url=http://fod.infobase.com/PortalPlaylists.aspx?wID=273866&xtid=34430

For a transcript of this video click here.

ARTE France (Producer). (2015). *Unbreathable: Cities on the verge of asphyxiation* [Video file]. Retrieved from https://libraryresources.columbiasouthern.edu/login?auth=CAS&url=http://fod.infobase.com/PortalPlaylists.aspx?wID=273866&xtid=114903

For a transcript of this video click here.

Danish Broadcasting Corporation (Producer). (2005). *Smog: The sweet smell of success?* [Video file]. Retrieved from https://libraryresources.columbiasouthern.edu/login?auth=CAS&url=http://fod.infobase.com/PortalPlaylists.aspx?wID=273866&xtid=35562

For a transcript of this video click here.

National Geographic Digital Media (Producer). (2007). *Coriolis effect* (Segment 14 of 18) [Video file]. Retrieved from https://libraryresources.columbiasouthern.edu/login?auth=CAS&url=http://fod.infobase.com/PortalPlaylists.aspx?wID=273866&xtid=40734&loid=90644

For a transcript of this video click here.