EARTH

AIR

FIRE

WATER

THE HUMAN ELEMENT

> *We can't see the air, but we still have an incredibly intimate relationship with it. You fill your lungs with air more than 20,000 times a day. So we can't avoid the fact that whatever we put into the air, we put into ourselves."*
>
> **—James Balog, *The Human Element***

AIR LESSON OBJECTIVES

At the end of this lesson, students will be able to:

- Explain the major components of air pollution, including particle pollutants, ground level ozone and greenhouse gases.
- Use visual evidence and scientific data to corroborate this explanation.
- Discuss how human behavior is changing air on Earth, how those changes are affecting humans, and how human efforts might help or ameliorate those changes.

MATERIALS

- You can find the Air Chapter here: **https://vimeo.com/328528959**. The password is: **THEedu**.
- Projection equipment to screen the Air Chapter of ***The Human Element***
- Printed copies of **Handout One—Air Note Catcher**
- Printed copies or an electronic version of an air map of your community
- As needed, printed copies of **Handout Two—Artist Statement** and/or **Research Appendices One–Three**

DURATION

Two 50-minute class periods

OPENING EXERCISE: CLIMATE CHANGEMAKER

Read aloud this introduction of Dr. Gabriella Pfister:

> *"Air doesn't know any boundaries. Air doesn't know if there is a border or when it crosses from one country into another one. Air just moves around with the winds."*

—Dr. Gabriella Pfister,
Deputy Director, National Center for Atmospheric Research,
in an interview for *The Human Element*

Dr. Gabriella Pfister is the Deputy Director of the Atmospheric Chemistry Observations and Modeling Lab at the National Center for Atmospheric Research (NCAR). Her work focuses on measuring pollutants in the air. She studies both how they interact as well as their travel patterns to assess how they impact local, regional and trans-continental air pollution. Her research serves as an empirical guide for policymakers formulating regulations for emissions standards of all kinds of activities—from car emissions to oil and gas research and agricultural output—to protect human health.[1]

Briefly discuss the following questions:

- What do you know about the causes of air pollution?
- What do you know about how air pollution has changed in your community over time?
- Where does the contaminated air in your community come from?

Project or pass out a map of your community and ask students to point out where they believe the main sources of air contamination come from.

Remind students of Dr. Pfister's research about how air pollutants travel, and have them draw arrows or use other symbols to signal where pollutants might come from elsewhere in your region. Use a resource like **Air Now** to locate the current air quality in your city or town and the surrounding areas.

Watch the Film Chapter "Air" (run time, 14:00)

Use **Handout One—Air Note Catcher** for students to record thoughts and questions as they watch. After the chapter finishes, offer students the opportunity to debrief about what they noticed or learned.

Revisit the community map students marked before watching the chapter, and add any new information.

EXPLORE THE HUMAN CAUSES OF AIR CONTAMINATION

Organize students into small groups for a jigsaw reading activity.

In round one, each group will become "experts" in one of three key terms related to air and air pollutants provided in the Research Appendices, or conduct independent research.

Term 1: Atmosphere, Layers of the Atmosphere (**Research Appendix One**)

Term 2: The Greenhouse Effect (**Research Appendix Two**)

Term 3: Pollution and Particulate Matter (**Research Appendix Three**)

- Define your term(s).
- Explain how **[your term(s)]** relates to air quality, air pollution and human health.
- Describe how **[your term]** is either affected by, or affects, climate change.
- Remark on whether and how **[your term]** is being addressed, or might be addressed by regulation, policies or human behavior changes.

What else did you learn about **[your term(s)]** ?

After students complete their research in small groups, have them reassemble in new groups to report their findings to one another. Then, as a large group, combine expertise to summarize data and findings and tell a story describing the interplay of human activity and science, and how these things together affect air quality.

Discussion questions:

- What plans or policies did you learn about that address air pollution?
- What positive technologies or approaches to reducing air pollution did you learn about that can be strengthened or bolstered? How?
- In your opinion, who is responsible for improving air pollution: individuals, industry, or the government?
- What is the connection between air pollution and climate change?
- After doing this research, what further questions would you like to explore?

EFFECTS: VISUAL EVIDENCE

Read these quotes aloud as a class:

> *"In less than half an hour, my balloon had floated up into what was essentially outer space. I found it incredible that our layer of air is so thin. For the first time in my life, I understood how finite and precious the air is."*
>
> **—James Balog, *The Human Element***

> *"Ozone is not a visible pollutant and that's why it is somewhat tricky, because people do not see it."*
>
> **—Dr. Gabrielle Pfister, *The Human Element***

Discuss: What kinds of visual evidence of air pollution and the effects of air pollution did you see in the film chapter?

Ask students to select images from the film chapter, thehumanelementmovie.com/air/, or from the research they did that represents either the human activities that create air pollution, or the human effects of air pollution.

When they have chosen an image, ask them to answer the following questions:

- What do you see in this image? Why did this particular image stand out to you?
- What does this image tell you about air pollution and/or the effects of air pollution?
- Where does the image come from? Do you trust what you see in the image? Why or why not?
- Who would you like to see this image, and what would you like them to learn?
- What ideas or actions does this photo suggest to you as you think about preventing or minimizing the harms of air pollution?

THE HUMAN ELEMENT OF CHANGE

> *"In protecting the climate, we are protecting the people. Contaminated air affects not just the stability of our climate, but also human health. The two things are connected."*
>
> **—James Balog[2]**

This lesson culminates with a project to help students synthesize their learning.

These projects can be completed during class time or assigned as homework. If you are planning to complete all four of ***The Human Element*** lessons, this portion of the lesson can contribute to the final culminating lesson.

1. Use the links on the **Air Now** site or other local resources to reach out to a person in your community or region. Ask about programs that address air pollution in your area.
2. Use art, photography, found objects, or other forms of creative expression to create two art pieces. The first piece represents one or more of the human causes of air pollution in your community. The second will represent how humans are affected by air pollution in your community. Use **Handout Two—Artist Statement** for a prompt and peer review.
3. Going back to the work of Dr. Gabriella Pfister, ask students to explore the relationship between science and policy. Write a short answer to the following questions:
    - What are the potential benefits and drawbacks of a scientist like Dr. Pfister suggesting that her data on emissions be used to influence policy?
    - What do you think is the responsibility of a city if it discovers that a pollutant released by its local power plant is causing asthma in children locally or in a town in the next state?

For an extended learning opportunity in environmental justice, see Research Appendix Four.

HANDOUT ONE

AIR NOTE CATCHER

As you watch, write down ideas, words, or phrases that stand out to you:

What is the film telling you about the current state of our air?

What further questions do you have?

HANDOUT TWO

ARTIST STATEMENT

Artist Statement:

Write a paragraph about your artwork and how it relates to human causes of air pollution and air pollution's effects on humans. Be sure to clearly state your message.

Peer Review Questions:

What message do you gain from the artwork and the artist's statement above?

What questions arose for you, and what would you like to know more about?

What did you like about this work?

What opportunities for growth do you see?

RESEARCH APPENDIX ONE

ATMOSPHERE, LAYERS OF THE ATMOSPHERE

> *"What we emit here at the ground . . . doesn't at some point disappear in space. What we emit stays in the layer of the air we breathe."*

—Dr. Gabrielle Pfister

The information below is adapted from the **University Corporation for Atmospheric Research (https://scied.ucar.edu/atmosphere-layers).**

Earth's atmosphere is a mixture of gases that surrounds our home planet. Besides providing us with something to breathe, the atmosphere helps make life on Earth possible in several ways. It shields us from most of the harmful ultraviolet (UV) radiation coming from the sun, warms the surface of our planet by about 33° C (59° F) via a naturally occurring greenhouse effect, and prevents differences between daytime and nighttime temperatures from becoming too extreme.

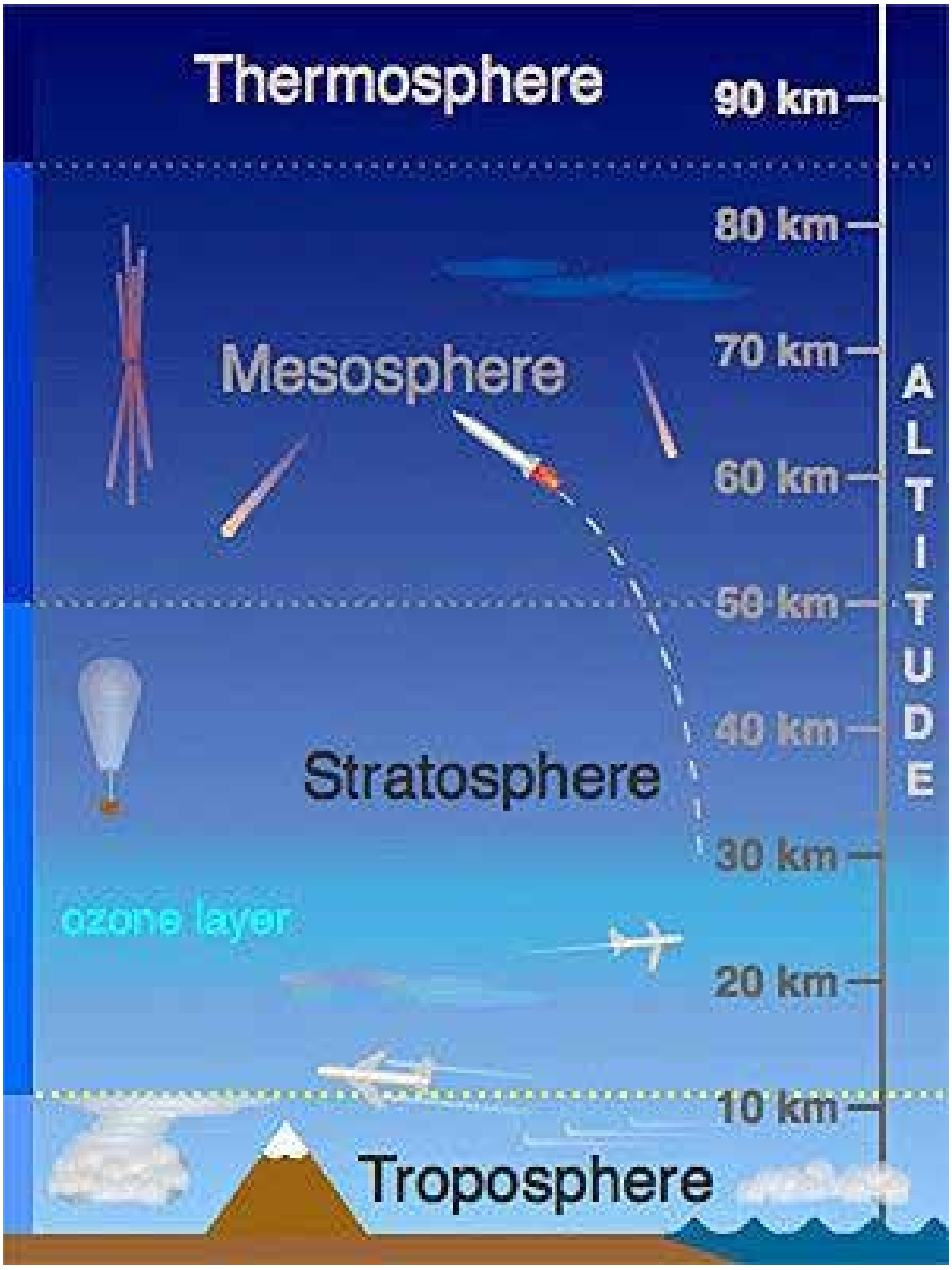
Gases in Earth's Atmosphere

Nitrogen and oxygen are by far the most common; dry air is composed of about 78% nitrogen (N_2) and about 21% oxygen (O_2). Argon, carbon dioxide (CO_2), and many other gases are also present in much lower amounts; each makes up less than 1% of the atmosphere's mixture of gases. The atmosphere also includes water vapor. The amount of water vapor present varies a lot, but on average is around 1%. There are also many small particles - solids and liquids - "floating" in the atmosphere. These particles, which scientists call "aerosols", include dust, spores and pollen, salt from sea spray, volcanic ash, smoke, and more.

Layers of Earth's Atmosphere

The atmosphere grows thinner (less dense and lower in pressure) as one moves upward from Earth's surface. It gradually gives way to the vacuum of outer space. There is no precise "top" of the atmosphere. Air becomes so thin at altitudes between 100 and 120 km (62-75 miles) up that, for many purposes, that range of heights can be considered the boundary between the atmosphere and space. However, there are very thin but measurable traces of atmospheric gases hundreds of kilometers/miles above Earth's surface.

There are several different regions or layers in the atmosphere. Each has characteristic temperatures, pressures, and phenomena.



Credit: Randy Russell, UCAR

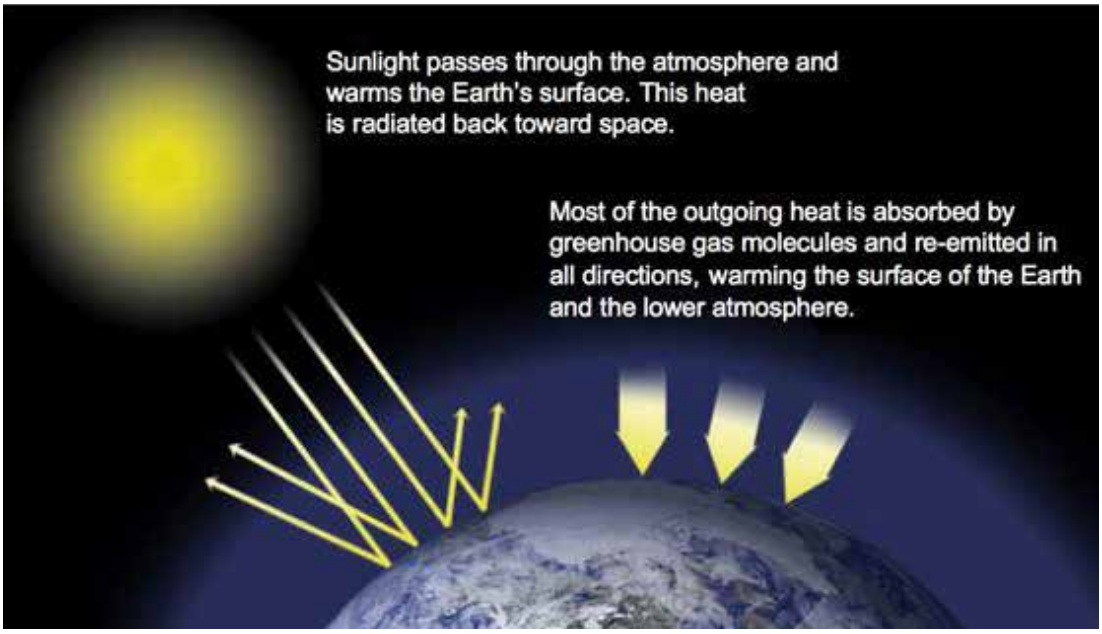
Earth's atmosphere has a series of layers, each with its own specific traits. Moving upward from ground level, these layers are called the troposphere, stratosphere, mesosphere, thermosphere and exosphere. The exosphere gradually fades away into the realm of interplanetary space.

RESEARCH APPENDIX TWO

GREENHOUSE EFFECT

***Article adapted from* NASA's Global Climate Change *website* (https://climate.nasa.gov/causes/).**

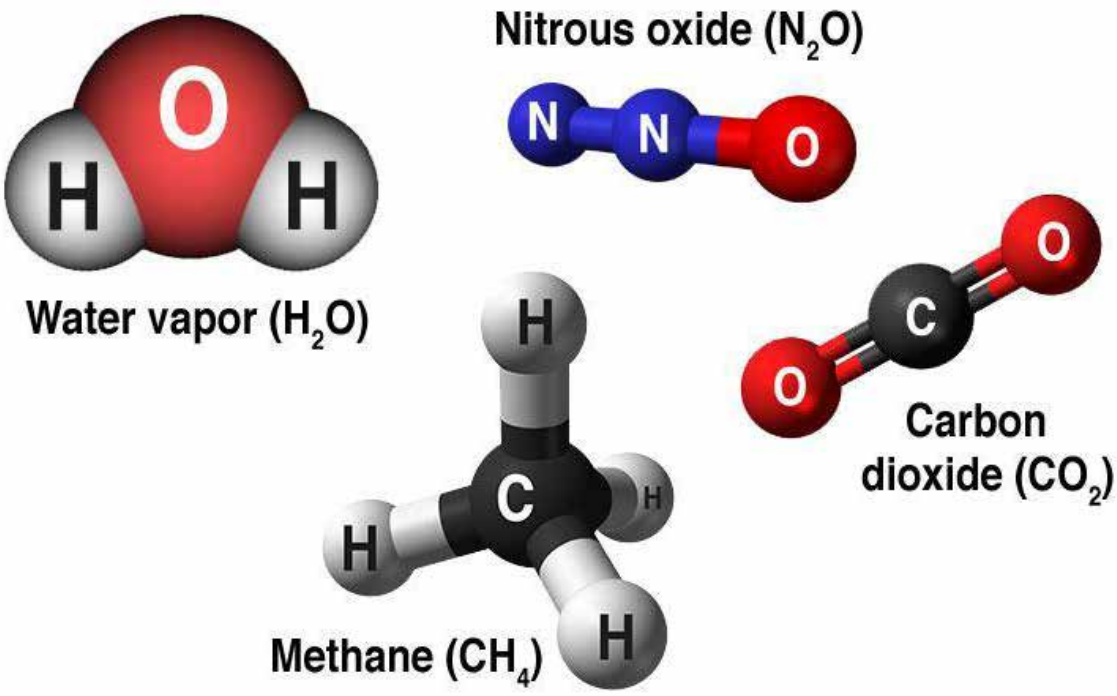
On Earth, human activities are changing the natural greenhouse. Over the past century, the burning of fossil fuels like coal and oil has increased the concentration of atmospheric carbon dioxide (CO_2). This happens because burning coal, oil, natural gas and even wood causes carbon to combine with oxygen, thus making CO_2: carbon dioxide. To a lesser extent, the clearing of land for agriculture, industry, and other human activities has also increased concentrations of greenhouse gases.



A blanket around the earth

A layer of greenhouse gases – primarily water vapor, and including much smaller amounts of carbon dioxide, methane and nitrous oxide – acts as a thermal blanket for the earth, absorbing heat and warming the surface to a life-supporting global average of 59 degrees Fahrenheit (15 degrees Celsius). The vast majority of climate scientists agree that the main cause of the current global warming trend is human intensification of the "greenhouse effect" — warming that results when the atmosphere traps heat radiating from Earth toward space.

The same gases in the atmosphere that make Earth habitable can, when present in excessive amounts, block so much heat from escaping that weather systems change and the climate warms. Long-lived gases that remain semi-permanently in the atmosphere and do not respond physically or chemically to changes in temperature are described as "forcing" climate change. Gases, such as water vapor, which respond physically or chemically to changes in temperature, are seen as "feedbacks": i.e., they "fuel" the greenhouse effect.



Feedback gases that contribute to the greenhouse effect include:

- Water vapor (H_2O). Water vapor increases as the Earth's atmosphere warms, but so does the possibility of clouds and precipitation, making these some of the most important feedback mechanisms to the greenhouse effect.
- Carbon dioxide (CO_2). CO_2 has a tremendous ability to increase the atmosphere's ability to trap heat. It is produced by natural processes such as respiration and volcano eruptions, and by burning fossil fuels. All plants absorb CO2, so when forests are cut down or grasslands dug up, there are fewer plants to absorb the gas. Human actions have increased atmospheric CO_2 concentration by more than a third since the Industrial Revolution began. This is the most consequential "forcing" of climate change.
- Methane (CH_4). Methane is a hydrocarbon gas produced both by natural sources mechanisms like the decomposition of plant matter and by human activities, including the decomposition of waste in landfills, agriculture (particularly rice cultivation), and livestock husbandry (cattle burps are an especially potent source of methane). On a molecule-for-molecule basis, methane is roughly 25 times more potent a greenhouse gas than carbon dioxide, but fortunately it is also much less abundant in the atmosphere.
- Nitrous oxide (N_2O). Nitrous oxide is a powerful greenhouse gas produced by soil cultivation practices, especially the use of commercial and organic fertilizers, fossil fuel combustion, nitric acid production, and biomass burning.
- Chlorofluorocarbons (CFCs). These are synthetic compounds entirely of industrial origin used in a number of applications. They are now largely regulated by international agreements due to their ability to contribute to the destruction of the ozone layer.

The consequences of changing the natural atmospheric greenhouse are well understood:

- Earth's average temperature has increased 1.6 degrees F (1.0 C) since the beginning of the Industrial Revolution in the late 1700s.
- The warming is not distributed evenly. Many areas of the Arctic, for example, have warmed by 4 degrees F or more. The Southwest U.S. has also heated up considerably more than the global average.
- The greenhouse effect tends to increase extremes of heating and precipitation.
- A stronger greenhouse effect is warming the oceans and increasing the melting of glaciers and ice sheets. This, in turn, raises the level of the oceans. Ocean water expands when it warms, contributing further to sea level rise (this is called "thermal expansion").
- Some crops and other plants respond favorably to increased atmospheric CO_2, growing more vigorously and using water more efficiently. At the same time, higher temperatures and shifting climate patterns are changing the areas where crops grow best and affecting the makeup of natural plant communities.

The role of human activity

In its Fifth Assessment Report, the Intergovernmental Panel on Climate Change, a group of 1,300 independent scientific experts from countries all over the world under the auspices of the United Nations, concluded that human activities over the past 50 years have warmed our planet. The panel's full Summary for Policymakers report is online at **https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_summary-for-policymakers.pdf**.

Solar irradiance

It's reasonable to wonder if changes in the sun's energy output would cause the climate to change, since the sun is the fundamental source of energy that drives our climate system.

Indeed, studies show that solar variability has played a role in past climate changes. For example, a decrease in solar activity is thought to have triggered the Little Ice Age between approximately 1650 and 1850, when Greenland was largely cut off by ice from 1410 to the 1720s, and glaciers advanced in the Alps. But several lines of evidence show that current global warming cannot be explained by changes in energy from the sun:

- Since 1750, the average amount of energy coming from the sun has either remained constant or increased slightly.
- If the warming were caused by a more active sun, then scientists would expect to see warmer temperatures in all layers of the atmosphere. Instead, they have observed a cooling in the upper atmosphere, and a warming at the surface and in the lower parts of the atmosphere. That's because greenhouse gases are trapping heat in the lower atmosphere.
- Climate models that include solar irradiance changes can't reproduce the observed temperature trend over the past century or more without including a rise in greenhouse gases.

RESEARCH APPENDIX THREE

POLLUTION AND PARTICULATE MATTER

Article adapted from **The U.S. Environmental Protection Association (https://www.epa.gov/no2-pollution/basic-information-about-no2#What%20is%20NO2).**

Nitrogen Dioxide (NO_2)

What is NO_2, and how does it get in the air?

Nitrogen Dioxide (NO_2) is one of a group of highly reactive gases known as oxides of nitrogen or nitrogen oxides (NOx). Other nitrogen oxides include nitrous acid and nitric acid. NO_2 is used as the indicator for the larger group of nitrogen oxides. NO_2 primarily gets in the air from the burning of fuel. NO_2 forms from emissions from cars, trucks and buses, power plants, and off-road equipment.

Health effects of NO_2

Breathing air with a high concentration of NO_2 can irritate airways in the human respiratory system. Relatively brief exposures to the gas 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 NO_2 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 of the health effects of NO_2.

Environmental effects

NO_2 and other NOx interact with water, oxygen and other chemicals in the atmosphere to form acid rain. Acid rain harms sensitive ecosystems such as lakes and forests.

The nitrate particles that result from NOx make the air hazy and difficult to see through. This affects the many national parks that we visit for the view.

NOx in the atmosphere contributes to nutrient pollution in coastal waters.

What is being done to reduce NO_2 pollution?

EPA's national and regional rules to reduce emissions of $NO_2$and NOx will help state and local governments meet the National Ambient Air Quality Standard (NAAQS). EPA identifies areas where the air quality does not meet the national NO_2 standards. For these areas, state and local governments develop plans to reduce the amount of NO_2 in the air. Enforcement of these standards has unfortunately been highly variable.

Particulate Matter (PM)

What is PM, and how does it get into the air?

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

Sources of PM

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

What are the harmful effects of PM?

Particulate matter contains microscopic solids or liquid droplets that are so small that they can be inhaled and cause serious health problems. Some particles less than 10 micrometers in diameter can get deep into your lungs, and some may even get into your bloodstream. Of these, particles less than 2.5 micrometers in diameter, also known as fine particles or PM2.5, pose the greatest risk to human health.

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

RESEARCH APPENDIX FOUR

EXTENDED LEARNING ABOUT ENVIRONMENTAL JUSTICE

This reading can be assigned as an extended reading outside of class for further learning about environmental justice, which is referenced but not explicitly discussed in the "Air" chapter.

Article adapted from **Environmental Justice and Air Pollution: The Right to a Safe and Healthy Environment (https://www.medscape.org/viewarticle/589135).**

Introduction

Historically, there are many reasons for environmental injustice: some economic, some aesthetic; some are simply due to a lack of available community resources. Today in the United States, low-income households and people of color are disproportionately affected by indoor and outdoor air pollution. Three times as many blacks compared with whites die from asthma; among children, this rate increases to 5:1. In some inner-city communities, one third of all black children have been diagnosed with asthma.

Lower income communities tend to be subjected to more pollution from industry, power generating facilities, highways and airports. When one community experiences more negative environmental consequences than another because of socio-economic differences, it produces an environmental justice (EJ) issue.

The EJ Movement

As described by the US Environmental Protection Agency (EPA), EJ is:

> *"...the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Fair treatment means that no group of people, including racial, ethnic, or socioeconomic group, should bear a disproportionate share of the negative environmental consequences resulting from industrial, municipal, and commercial operations or the execution of federal, state, local, and tribal programs and policies."*

The EJ movement in the United States goes back to the end of the 20th century, and was officially recognized as an area of governmental concern during the administration of President Bill Clinton. No federal regulations exist in regard to EJ, therefore leaving it up to states and communities to take action. At the moment, little legal recourse is available for many of these communities.

Asthma

Asthma is more prevalent in poorer communities. Children with asthma are more prone to also react to tobacco smoke, dust mites, mold arising from dampness in housing units, and pet dander. The following efforts have been associated with fewer asthma attacks:

- Educating families about such hazards;
- Providing bed coverings and cleaning supplies; and
- Fixing leaky plumbing.

It is important to remember that it's not only children who suffer. Parents also experience consequences (e.g., losing workdays—often uncompensated—when they must take care of a child experiencing an asthma attack).

Asthma is often not managed as well as it should be due to lack of: education, access to healthcare, and access to drug regimens that prevent recurring attacks.

Children who are taught to monitor their own lung function and are given medications for both chronic and acute use are better able to manage their asthma. Excellent documentation now shows that in communities with special programs to educate families and provide regular medication to children, the number of asthma deaths and visits to emergency departments can be greatly diminished.

For people of all ages and socioeconomic statuses, another area of concern is the buildup of potentially harmful materials in indoor air. With the advent of much better insulation of buildings in the 1970s, coupled with far fewer air exchanges per hour, "tight building" or "sick building" syndrome can occur. This is especially prevalent in new or renovated construction when there is off-gassing of potentially harmful materials from carpeting, furniture made from pressed board, and other products that enter the indoor air and build up over time. Airing out facilities after construction or renovation can help, as can ensuring sufficient fresh air exchanges each hour and air filters.

ENDNOTES

1 https://staff.ucar.edu/users/pfister
2 Interview on NPR's Fresh Air, February 6, 2019