

Introduction Presentation Slide Notes

The notes below match those provided as slide notes in the *Air Quality Introduction Presentation*, a PowerPoint® file. They are made available here in case you want to print them out.

Slide 1: (title slide) An Introduction to Air Quality

Slide 2: Learning Goals: After this lesson, you will be able to...

- List and describe the three primary reasons to study air quality: health effects, climate change and aesthetics.
- Explain the differences between primary and secondary pollutants, and gas-phase and particulate pollutants.
- Explain the different sources of CO and CO₂ (biological and combustion), VOCs (combustion and volatilization), and NO₂ (combustion)

Slide 3: What sets the Earth apart from other planets and makes it possible for us to live here?

- The atmosphere enables life to flourish on our planet, and more specifically our atmosphere is just right.
- Other planets have little or no atmosphere, such as Mercury, or thick/inhospitable atmospheres, such as Venus.

Slide 4: The atmosphere is a thin planetary skin.

- You could compare the radius and thickness of our atmosphere to an apple's skin. The takeaway: Our atmosphere is a thinner cover for our planet than an apple's skin is for the apple.

Slide 5: What gases make up our atmosphere?

- Begin by having students take guesses.
- The answer you are looking for is oxygen (21%), nitrogen (78%) and trace gases (1%).
- Every gas in our atmosphere EXCEPT for oxygen and nitrogen are "trace gases."

Slide 6: The structure of the Earth's atmosphere

- **Takeaway message:** The Earth's atmosphere is complex. It is not the same everywhere on Earth, and it is not the same vertically.
- **More information:**
 - Our atmosphere is divided into vertical layers, which are defined by temperature; temperature drops through the troposphere and then rises again in the stratosphere, this switching point is what defines the tropopause.
 - The dynamics determine whether or any vertical movement exists; in some cases, pollutants are trapped in certain layers, and in others they can move freely.
 - **Why this matters:** Imagine a volcano erupts; depending on the conditions and where it occurs, the ash and gases may settle locally—causing local air quality issues—OR they may be transported up into the atmosphere and then transported to other parts of the planet—where they may cause problems regionally.
 - Learn more about our atmosphere (including the layers and dynamics at: <http://scied.ucar.edu/shortcontent/earths-atmosphere>)

Slide 7: What do you think of when you hear "air quality"?

- *Ask the class:* What does AQ mean?

- Air quality research entails studying how different activities are changing the composition of our atmosphere, and then trying to understand how those changes might impact human and environmental health.
- *Ask the class:* Is air quality the same all over the planet? Why or why not?
 - No, different pollutants are emitted in different places and pollutants can behave differently based on local conditions (such as geography); air quality issues can be local, regional and even global—meaning some pollutants stay where they are emitted and some are transported across the globe (which is governed by complex atmospheric chemistry and dynamics).

Slide 8: What types of air pollution exist?

- Particulate matter pollution is dust and tiny particles,
 - varying from approximately .01 microns to 1,000 microns
 - (1 micron = 1 micrometer = .000001 meters)
 - Composition: May include inorganic particles (dust, soot, ash, salt spray over the oceans, etc.) and/or organic particles (bacteria, mold and pet dander allergens, etc.).
 - Behavior: Larger particles are heavy enough to settle out; lighter/smaller particles remain suspended in the atmosphere.
- Gas-phase pollution is made up of molecules
 - They can range from small molecules (like NO) to larger hydrocarbon chains.
 - Sources: They can volatilize from liquids or solids; they can also be released through processes like combustion and respiration; some gases play a role in nutrient cycling (such as CO₂ in the carbon cycle).

Slide 9: Pollutant Size and Classification

- A diagram plots where different pollutants fall across a size distribution (in micrometers).
- It also provides examples of particulate pollutants: pollen, mold spores, dust mite allergens, bacteria, cat allergens, viruses, dust of various granularity, cement dust, fly ash, oil smoke, smog, tobacco smoke, soot.
- Note the difference between pollen and dust that we can see, and viruses, and then gases.

Slide 10: Primary vs. Secondary Emissions

- Primary emissions are DIRECTLY emitted from products, such as VOCs (like paint fumes), combustion such as CO₂ and CO (from fires), and CO₂ from human respiration.
- Secondary emissions are FORMED in the atmosphere from primary emissions (such as ozone).
- *Ask the class:* In this diagram, which are the primary emissions? The secondary emissions? (Answer: The primary emissions are those exiting from the tailpipe and smokestacks, while secondary emission is ozone that forms in the presence of sunlight via a photochemical reaction.)

Slide 11: Our Focus: Gas Phase

- These pollutants (with the exception of NO_x) are measurable with the air quality monitors (Pod) we will be using and will be the focus throughout the activities. All the pollutants are listed on this slide so it can serve as a resource; for example, you could print it out or leave it projected during activities.
- **CO₂:** Carbon dioxide gas is the product of biological respiration; animals exhale it and then plants use it; it is also a product of combustion. Whenever a carbon-based fuel is burned with plentiful oxygen, all of the carbon molecules are converted to CO₂.

- **NO and NO₂ (or NO_x):** These gases result from high-temperature combustion and play an important role in atmospheric chemistry. The formation of NO_x does not include the fuel itself, rather the nitrogen in the air (remember, 78% nitrogen) is in the form of N₂ (or 2 nitrogen molecules bonded together), but at high temperatures, these N₂s get broken up and the single Ns are bonded to 1 or 2 oxygen atoms.
- **VOCs** are volatile *organic compounds* (in chemistry, organic means the molecule contains carbon). VOCs may be produced with incomplete combustion or the carbon in fuel cannot get all the way to CO₂, which may happen if not enough oxygen is present. We call this phenomenon **incomplete combustion**; carbon monoxide (CO) is also a product of incomplete combustion. In addition to combustion products, VOCs are also any organic compound that can volatilize (enter the gas phase) at room temperature and pressure, which means hundreds of compounds qualify as VOCs. Think about it this way: most things we can smell are VOCs, such as gasoline vapors, cleaning supplies, paints, bacon sizzling in a pan, and plants, like pine trees). Another term for VOCs is hydrocarbons.
- **CO:** CO is a primary pollutant—it is formed from incomplete combustion, and photochemical reactions in the atmosphere. CO is a colorless, odorless gas that can be dangerous when present in high quantities at ground level and can even kill you— make sure your family has a carbon monoxide monitor in your home! Higher up in the atmosphere, it is NOT a greenhouse gas but participates in many important photochemical reactions that form other greenhouse gases such as CO₂ and O₃ (ozone), so when more CO is emitted, more greenhouse gases are formed.

Slide 12: Our Focus: Particulate Matter

- The air quality monitors (Pod) we will be using will also have the capability to measure these specific sizes of particulate matter (PM). Particulate matter is both a primary and secondary pollutant. Primary source examples include incomplete combustion, automobile emissions, dust and cooking. A secondary source of particulate matter include chemical reactions in the atmosphere.
- PM₁₀ are particles smaller than 10 microns and are the largest size of particle that the pods measure. They are particles that can often be seen with the human eye and examples include pollen, heavy dust, and fly ash. They are small enough to be inhaled, and cause irritation to the eyes, nose, and throat
- PM_{2.5} are particles that are smaller than 2.5 microns. Examples include settling dust, bacteria, allergens and mold spores. PM_{2.5} is considered more dangerous than PM₁₀ because, once inhaled, it can enter the bloodstream through the alveoli in the lungs.
- PM₁ are particles that are smaller than 1 micron. Examples include tobacco smoke, smog, soot, viruses, and suspended atmospheric dust. Similar to PM_{2.5}, PM₁ can enter the bloodstream through the alveoli in the lungs, and penetrate even further into the body.
- Generally, the smaller the PM, the further it can penetrate into the body.
- As noted in slide 9, please note that particulates may also be liquid, or a mixture of solid and liquid.

Slide 13: What are the main causes of air pollution?

- Discuss the various mechanisms of pollution formation and sources—what types of pollutants might come from which source.
- Note that pollutants come from both natural and anthropogenic (human-made) sources.
- Combustion is a major source of pollution' two examples are vehicles and forest fires, however, both of these sources are burning different fuel-types in different conditions, meaning the emission profiles will likely be quite different (potential pollutants: CO₂, NO_x, CO, VOCs, PM).

- Compound volatilization (VOCs discussed on the previous slide) also results in emissions. Industrial activity is a good example of where VOCs might be regulated to both prevent health impacts to workers and emissions into the atmosphere. (Point to the oil refinery photo.)
- Physical generation includes both human-made and natural occurrences, but the result is always dust or particulate matter, whether it is a desert wind storm, or a car on a dirt road, the result is more particulates in the atmosphere.
- Something else to remember is that all of the pollutants, regardless of how they were generated, can also interact with each other, and change chemically or physically in the atmosphere.
- “The solution to pollution is dilution” used to be a saying when it came to managing air and water quality pollutants; however, this is no longer true. Many studies have confirmed that air pollutants generated in every country affect the rest of the world. For example, pollutants have been detected in the U.S. that originated in China—just one example. Dilution is not a solution.

Slide 14: Temperature Inversions affect dilution and how pollutant’s disperse

- This meteorological phenomena is an example of how the weather can worsen air quality problems.
- Normally, warm air at the surface rises, creating vertical movement. However, if you end up with a warm air mass on top of a cold air mass (which is especially common in valleys and places next to mountains), the warm air above and cold air below are already where they want to be, creating stagnant conditions.
- The inversion point at the boundary between the cold and warm air acts almost like the lid of a box, trapping pollution below.

Slide 15: Transition slide to the “The Bigger Picture”

Slide 16: Why does air quality matter?

- Have students either discuss in small groups, or raise their hand and share their ideas.
- Look for answers encompassed by these three larger categories:
 - *Human and environmental health:* Some gases and particulate types can be dangerous to both
 - *Climate change:* Greenhouse gases affect climate, which impacts weather, storms, oceans, glaciers, plants and animals.
 - *Aesthetics:* Poor visibility can cause economic problems for places that rely on tourist dollars, which happened at the Grand Canyon in the 1960s. Odors can affect the quality of life for entire neighborhoods located near factories and oil refineries.

Slide 17: Health Impacts: An example—1952 London Smog Event

- On December 4th 1952, a combination of pollution and weather conditions resulted in the deaths of more than 4,000 people.
- Looking at the plot, notice the high correlation between pollution (smoke and sulfur dioxide) and the deaths per day; although the timeline on the graph is hard to see, the rise in deaths appears to be a change from the baseline conditions prior to the event.
- The pollution was a combination of power plants and industrial activity, along with emissions from home furnaces burning coal.
- Cheaper coal tends to have a lot of sulfur in it, resulting in SO₂ or sulfur dioxide, when it is burnt. Today, we usually have control technologies in place that can both remove the SO₂ and particulates from power plant emissions.

- **FYI:** Sulphur dioxide = gas-phase pollutant (SO₂ molecule); smoke = particulate.
- See a short summary, *Smog Kills Thousands in England*, at: <http://www.history.com/this-day-in-history/smog-kills-thousands-in-england>

Slide 18: How do we protect U.S. citizens' health?

- It is interesting to note, that while it is called the ENVIRONMENTAL Protection Agency, the primary purpose of most regulations enforced by the EPA is to protect human health; environmental health is somewhat secondary.
- Additionally, the EPA can only regulate outdoor air. OSHA, Occupational Safety and Health Administration, can regulate indoor air quality in workplaces such as factories or plant; however, no regulations exist for indoor air at home.

Slide 19: Health impacts: An example—Cookstove Emissions

- Approximately half the world cooks their everyday meals over open fires, resulting in high pollutant exposure. Because women are primarily doing the cooking, they are also the most at risk for this exposure.
- From using cookstoves, the pollutants we worry about include particulate matter, carbon monoxide, and VOCs.
- Many research groups are working to tackle this problem from all angles. Some researchers are developing affordable stoves that are more efficient and achieve more complete combustion (producing CO₂ rather than VOCs and CO); other researchers are collecting air quality data to assess exposure, and social scientists are investigating to understand what affects the adoption of a new technology like a better cookstove.

Slide 20: Climate Change and Air Pollution

- Carbon dioxide, methane, and ozone are pollutants that we will be talking about that are also greenhouse gases (GHGs).
- Once energy from the sun enters our atmosphere, a number of things can happen. Some of the energy is absorbed by the Earth and in turn the Earth gives off heat. This heat may escape into space or be absorbed by greenhouse gases. Then, these gases either radiate the heat into space or back to Earth.
- Looking at the diagram, you can see how an increase in greenhouse gases results in less of this heat escaping to space and more radiating back to Earth, warming the planet.

Slide 21: Aesthetics Impacts of Air Pollution

- Discuss with students their experiences with smog and smells. If you live in or near a valley, students may be familiar with temperature inversions that trap pollution and cause haze to settle at lower elevations.
- Industrial areas of cities may have odors like tar or other unpleasant chemical smells that come from factories and refineries. Everyone has probably experienced the smell of gasoline when you fill up your car.

Slide 22: Transition to Air Quality Monitoring Technologies

Slide 23: A quick note about common units

- Introduce to students the units they will see for air quality measurements.
- For AQ studies, we need to know concentration:
- **ppm or ppb** = parts per million or parts per billion
 - EXAMPLE: Imagine you have 1 million water bottles and 400 are filled with CO₂ while the rest are filled with air—by volume you have 400 ppm of CO₂
- **µg/m³** = micrograms of pollutant per meter cubed of air

- This is the total weight of particulates (for example) that you have, per meter cubed of air

Slide 24: What are we measuring?

- *Ask the class:* How do research scientists and engineers measure air quality? How do we detect invisible gases in the air? What about PM? (Depending on the size, and concentration, PM may be invisible too.)
- Answer: Essentially, we examine optical or physical properties, or induce a change and measure its magnitude.
- **Optical properties:** Some gases absorb particular wavelengths of light (think of the visible and infrared light portion of the electromagnetic spectrum). Some instruments shoot a laser of this wavelength of light through space, and depending on how much makes it to the other side (which we measure), we can determine how much was absorbed and how much of a particular gas is in the sample (as illustrated in the slide diagram).
- **Physical properties:** With particles often we look at physical properties. If we collect them on a filter (as in the slide photo), we can weigh the filter and see the color (color may indicate source). Different-sized particles behave differently in the air (heavier ones settle, lighter ones float), so we take advantage of these behaviors and separate particle samples into size brackets. Then we weigh or use other instruments to determine how much of each size we have.
- **Measuring a change:** One example is using an FID—a flame ionization detector. Essentially, you burn an air sample and based on the energy released (collected and measured), you estimate the amount of carbon present (and thus hydrocarbons). Many sensors also work this way; specific gases interact with a material on the surface, causing a change in the sensor itself, and we correlate that change in the sensor with the gas concentration.

Slide 25: Conventional Monitoring Equipment

- Regulators rely on high-quality expensive instruments that take advantage of the principles discussed in the previous slide.
- These instruments cost \$5,000 - \$100,000, but this high-quality instrumentation is necessary for both scientific research and regulatory work.
- Cities and states must prove that they are meeting EPA standards, and networks of high-cost monitors help regulators determine whether or not the standards are being met and why, if they are not.

Slide 26: Next-Generation Monitoring Equipment

- Low-cost sensors are making it possible for new low-cost accessible technologies to be built. EPA calls these next-generation monitoring technologies.
- This is the type of technology you will use for the upcoming activities and your research project.
- Having many low-cost instruments enables us to collect data with much higher spatial and time resolution. One day these technologies may even supplement our existing conventional monitors (the high-quality ones in the last slide).
- While this new technology is not complete “figured out” yet, many research groups are building and using them successfully.
- Another exciting point is that because these technologies are low-cost and fairly easy to use, it makes them accessible to the public, which means that one day, data collected by citizens might supplement data collected by regulators.

Slide 27: Pods

- If you rented monitors from the University of Colorado Boulder, this is what they look like and this is what you will be using for data collection.
- They are versatile. They can be used indoors or outdoors. They may be used for stationary monitoring or battery-powered for mobile monitoring.
- They are capable of collecting a wide range of data: CO₂, total VOCs, PM and CO, as well as temperature, humidity, wind data and GPS locations.
- More information on the Pod monitors—how they work, the sensors, and the measurements available—is in the Appendix Presentation.

Slide 28: Transition to Control Technologies

- Engineering enters into air quality research in many ways, for example, developing new tools to measure pollutants, designing a study to answer a question, and finding solutions to air quality issues, which can include control technologies (such as the catalytic converter in your car), or mitigation strategies (such as preventing the emission or formation of pollutants).

Slide 29: Control Technologies Overview (1)

- *Ask the class:* How can we remove particles from the air?
- Answer: In homes with “central air” systems for heating and cooling, a filter prevents particles from circulating throughout their homes.
- Factories and some businesses use this same approach on a larger scale. Depending on the size and composition (what they are made of), different techniques are used. The diagrams show two examples of control devices.
 - **Cyclone:** Larger particles, subject to inertial forces, “fall out” into the collection area, while the now-clean air escapes through the top.
 - **Electrostatic precipitator:** Small particles are given a charge and collected on oppositely charged plates, which are then cleaned periodically.

Slide 30: Control Technologies Overview (2)

- *Ask the class:* What about gases?
- Gases can either be captured or burned.
 - **Scrubber:** These devices spray water through pollutant-laden air, and certain gases and particles are trapped in the water, thus cleaning the air. The resulting water is still polluted and must be further treated.
 - **Flaring:** Another option is to burn polluted air. For example, if you have air containing toxic VOCs, burning it completes the combustion process, turning the VOCs into CO₂. Even though it is a greenhouse gas, CO₂ is not directly harmful to humans. Using the flaring technique is common in oil and gas operations.

Slide 31: Control Technologies in Daily Life

- While most people have never encountered a scrubber, plenty of technologies designed by engineers to minimize our exposure to air pollution are at use in our daily lives, such as the three examples on this slide.
 - Stove “fume hoods” include a fan that pulls cooking emissions up and out of homes.
 - Carbon HVAC filters catch large dust particles in homes with central HVAC systems; the carbon helps get rid of odors since hydrocarbons and VOCs stick to carbon).
 - Catalytic converters are required on automobiles; they create a chemical reaction that converts the gases in vehicle emissions into water vapor and less-harmful and even inert matter. Adding them to vehicles eliminates 90% of the polluting gas emissions that would otherwise exhaust out the muffler.

Slide 32: Control Technologies Overview (3)

- In addition to removing pollutants, we can prevent them from being emitted in the first place.
- For example, some parts of Colorado have exceeded the EPA's ozone standard. While regulators may develop new regulations that limit what industry can emit, public opinion campaigns can change individuals' behaviors and help to reduce their contribution to the problem.
- For example, the subway shown here is an example of public transit, which results in less pollution per person than if everyone used their own vehicles.
- This OzoneAware public awareness campaign is an attempt to minimize vehicle emissions so as to reduce production of the ingredients that form ozone.
- The campaign recommends that you do not idle your car (to minimize NO_x and VOCs), take public transit (also limiting NO_x and VOCs), and mow after dark. Lawn mowers and ATVs often have engines that lack the control technologies required on cars, thus they release a lot of VOCs. By having people do these activities after dark, it is less likely that their VOCs will be used for O₃ formation, which requires sunlight.

Slide 33: Conclusions

- We care about air quality because of health, climate change and aesthetics.
- Air pollution comes from combustion, mechanical production and volatilization.
- Engineers use a wide variety of monitoring technologies to understand what is in our air.
- Engineers develop and implement control technologies and mitigation strategies to improve air quality.
- Discuss and answer any student questions.
- Also, the (optional) *Presentation Appendix Slides* explain more about the Pod—how it works, the sensors, the measurements available, etc.