Air Quality Resources
Module 9

WHAT IS AIR QUALITY?

The definition of Air Quality has many different variations depending on the context. Air Quality can be "a measure of the condition of air relative to the requirements of one or more species and or to any human need or purpose." It can also be "a measurement of pollutants in the air." In another more broad sense, it is "a description of the healthiness of the air."

The discrepancy or variation in definition is due in part to two things:
1. Air Quality can be described in both Qualitative and Quantitative terms.
2. Advances in Science and Technology have changed the ways that we are able to measure and describe Air Quality over time.

What all of the definitions seek to accomplish is to describe the relationship between various concentrations of pollutants in the air with the health of human beings and their surroundings.

Below is a figure that shows the Air Quality Index (AQI) as outlined by the US Environmental Protection Agency (EPA). Note the usage of three indicators that are all interlinked: the AQI Value (numerical), Level of Health Concern (textual), and threat color (visual).

AIR QUALITY INDEX

Air Quality Index (AQI) Values	Levels of Health Concern
0 to 50	Good
51-100	Moderate
101-150	Unhealthy for Sensitive Groups
151-200	Unhealthy
201-300	Very Unhealthy
301 to 500	Hazardous

WHAT IS AIR POLLUTION?

"Airborne particles and gases occurring in concentrations that endanger the health and well-being of organisms or disrupt the orderly functioning of the environment."
–Lutgens and Tarbuck

Air Pollution is divided into two sub-categories:
PRIMARY POLLUTANTS and SECONDARY POLLUTANTS

PRIMARY POLLUTANTS

These are airborne particulates that are emitted into the air directly from an identifiable process or source. These tiny structures are collectively known as PARTICULATE MATTER (PM).

Particles being emitted often become "suspended" in either the air or the water vapor aloft in the various levels of the atmosphere. Once a particle becomes suspended, it becomes known as an AEROSOL.

Primary Pollutants can be emitted from many different sources, both Anthropogenic and Natural.

Anthropogenic Sources:
Combustion Processes
Chemical Processes
Nuclear or Atomic Processes
Roasting, Heating and Refining Processes
Mining, Quarrying and Farming Processes

Natural Sources:
Volcanoes
Breaking Seas
Pollens and Terpenes
Fire
Blowing Dust
Bacteria and Viruses

To the right is a list of the Major Primary Pollutants that are emitted by these sources.

Major Primary Pollutants:
Particulate Matter ($PM_{(x)}$)
Sulfur Dioxide
Nitrogen Oxides
Volatile Organic Compounds (VOC)
Carbon Monoxide
Lead

How are Primary Pollutants Spread?

"Dilution is the solution to pollution"

There are two major mechanisms that affect how airborne pollutants are spread:

WIND and MIXING DEPTH

Wind

Wind causes bodies of polluted air to spread out across the Earth. When winds are high, these bodies of polluted air travel further distances and are thus spread out over a larger area. This leads to a lower concentration of pollutants per volume of air.

On the other hand, when winds are low, the polluted air is not able to spread over such a large area. This leads to a much higher localized concentration of pollutants and causes the air to "stagnate" over a small area.

Mixing Depth

The layer of air between the surface of the Earth and the height at which atmospheric convection begins to occur is called the MIXING DEPTH or MIXING HEIGHT.

Deeper MIXING DEPTHS allow pollutants to be dispersed within a larger volume of air, leading to greater dilution of pollutants.

Shallower MIXING DEPTHS "trap" pollutants in a small volume of air, which does not allow bodies of pollutants to disperse as quickly.

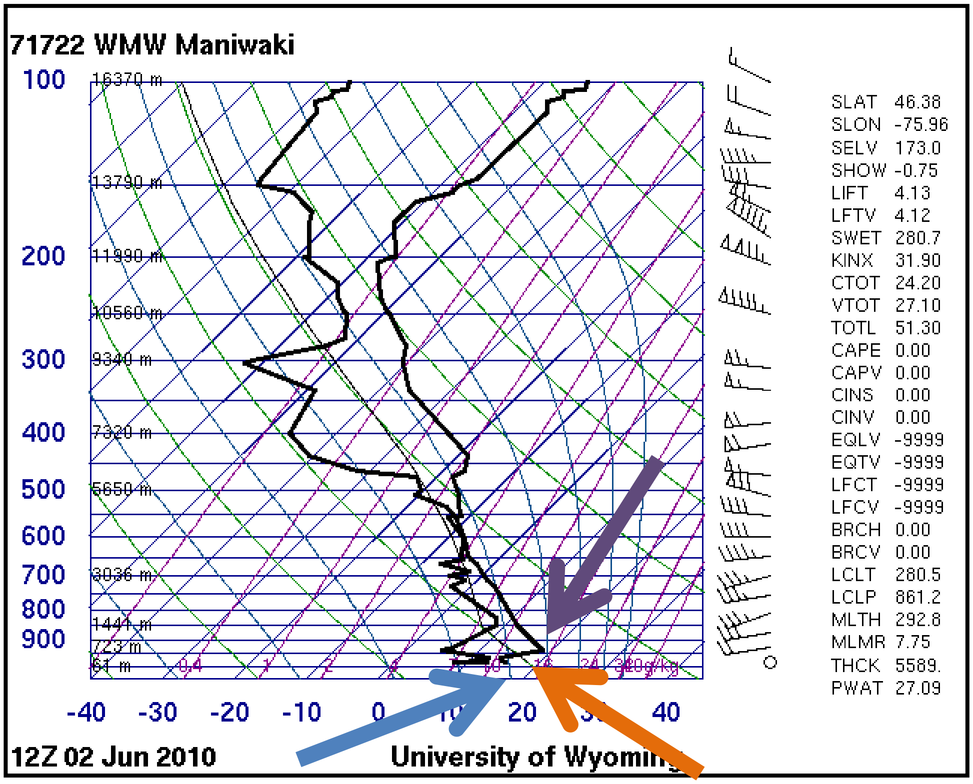
For a visual example of mixing depth, refer to the powerpoint slides.

This website from New Zealand also offers a good explanation of mixing depth:

http://www.ew.govt.nz/environmental-information/All-about-air/Weather-affects-air-quality/

SKEW-T and Mixing Depth

SKEW-T charts can help understand why pollution gets trapped in lower levels.



Air temperature starts off getting COLDER as elevation increases.

INVERSION LAYER

Air temperature begins getting WARMER as elevation increases, creating a "cap" over the cold air.

THIS CAP IS WHAT CONTROLS MIXING DEPTH

This figure is also available in the PowerPoint

In general, air temperature decreases with increasing altitude starting from ground level in the troposphere. This is subject to change however, depending on the movement of air masses.

In High Pressure situations, compression of the air in the upper parts of the troposphere can cause "friction" between molecules that warms the air MORE than the layer of air at the ground level.

When there is a change in lapse rate, an INVERSION occurs.

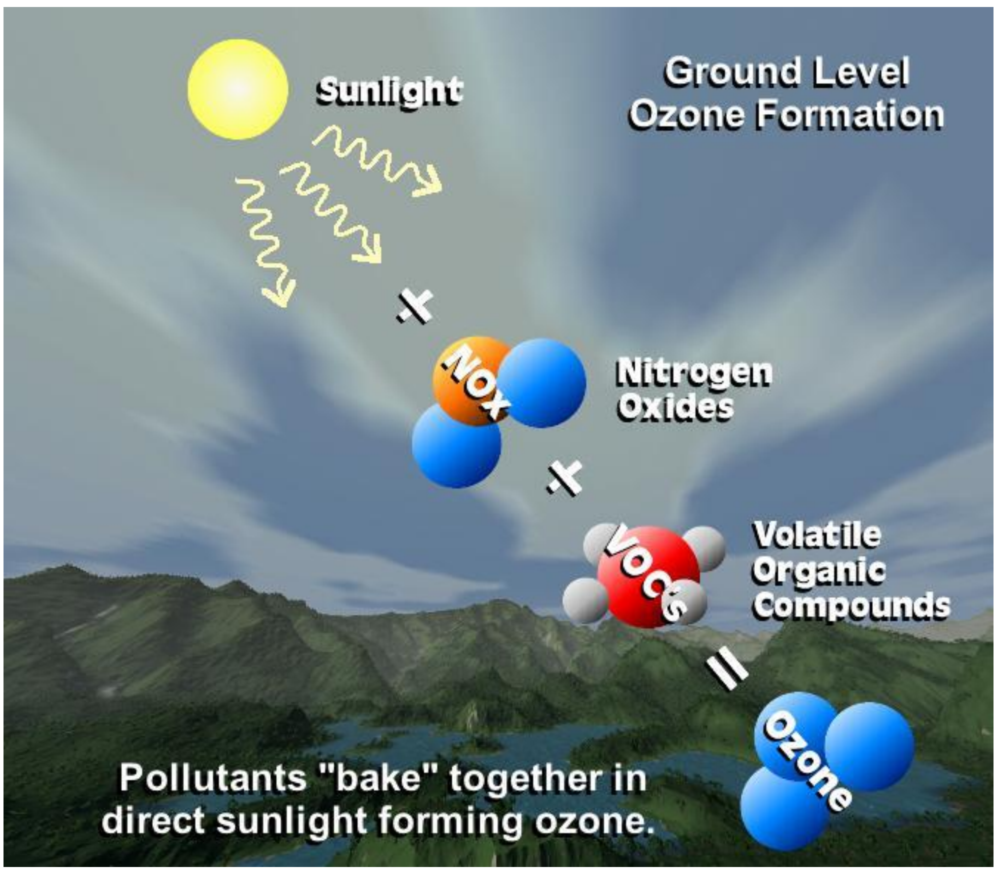
Warm air from industrial burning and combustion emissions is warmer than the cool air at the ground level, and thus rises.
It is able to rise so long as it remains warmer than the surrounding air.

When there is an INVERSION in the atmosphere, the pollution is no longer able to rise. Remember that MIXING DEPTH (in this situation the altitude of the inversion above the ground) is a factor that controls the evacuation of polluted air from an emissions source.
When there are low level inversions, polluted air masses can stagnate below the inversion. A clear example of this phenomenon is visible in this photograph:

SECONDARY POLLUTANTS

These are pollutants that *are not directly emitted from some process*, but rather *form as the result of interactions between primary pollutants and the air around them.*

SECONDARY POLLUTANTS
SMOG (Smoke + Fog)
Ground Level Ozone (NO_x + Volatile Organic Compounds "VOCs")
Peroxyacetyl Nitrate (also NO_x + VOCs)



$$NO_2 + E_{(sun)} \longrightarrow NO + O$$

$$O + O_2 \longrightarrow O_3$$

$$O_3 + NO \longrightarrow NO_2 + O_2$$

$$NO_2 + R_{(Hydrocarbon)} \longrightarrow PAN$$ (Peroxyacetyl Nitrate)

Smog is a term that was coined in 1905 in London to describe the dark "fogs" that lingered throughout the city during the industrial revolution. Smog can be broken down into two types: "Smokey Fog" and "Photochemical smog."

Smokey Fog is often described as "London" smog because it resembles the dark, greyish clouds that would have over the city during the 19th and 20th century industrial revolutions. It forms when coal or other industrial burning emits soot into the atmosphere. This soot then serves as condensation nuclei for water vapor in the air, ultimately resulting in a combination of the two.

Photochemical fog is commonly called Los Angeles type smog, and is fundamentally different from smokey fog in terms how it forms. Combinations of Aldehydes, Nitrogen Oxides, PAN, Tropospheric Ozone, and Volatile Organic compounds are released through combustive activities and undergo different chemical reactions when interacting with energy from the sun. These reactions yield highly oxidized noxious chemical mixtures that generally cast a brownish haze over urban areas that receive plentiful sun.

Smog Resource:

UC Berkeley Smog Explanation:
http://are.berkeley.edu/courses/EEP101/spring03/AllThatSmog/back.html

NASA information on SMOG bloggers:
http://www.nasa.gov/topics/earth/features/smogbloggers.html

University of Maryland SMOG BLOG:
http://alg.umbc.edu/usaq/

"Smog City 2" Interactive classroom activity – Smog Simulator:
http://www.smogcity2.org/

Explanation of Photochemical SMOG
http://mtsu32.mtsu.edu:11233/Smog-Atm1.htm

Salt Lake City SMOG Timelapse Loop
http://www.time-science.com/timescience/projects_meteo.asp

Ground Level Ozone Resource:

US EPA:

http://www.epa.gov/glo/

VOCs

http://www.epa.gov/iaq/voc.html

Particulate Matter (PM)

Particulate Matter refers to the fine, micro shards of matter that become suspended in liquid or gas. PM can be emitted by human processes or released naturally. PM is described and classified by its particle diameter. This diameter is generally given in micrometers (µm), with sizes ranging from PM_{10} (Particulate Matter with a diameter of 10 µm) down to UFP ($PM_{<=0.1µm}$).

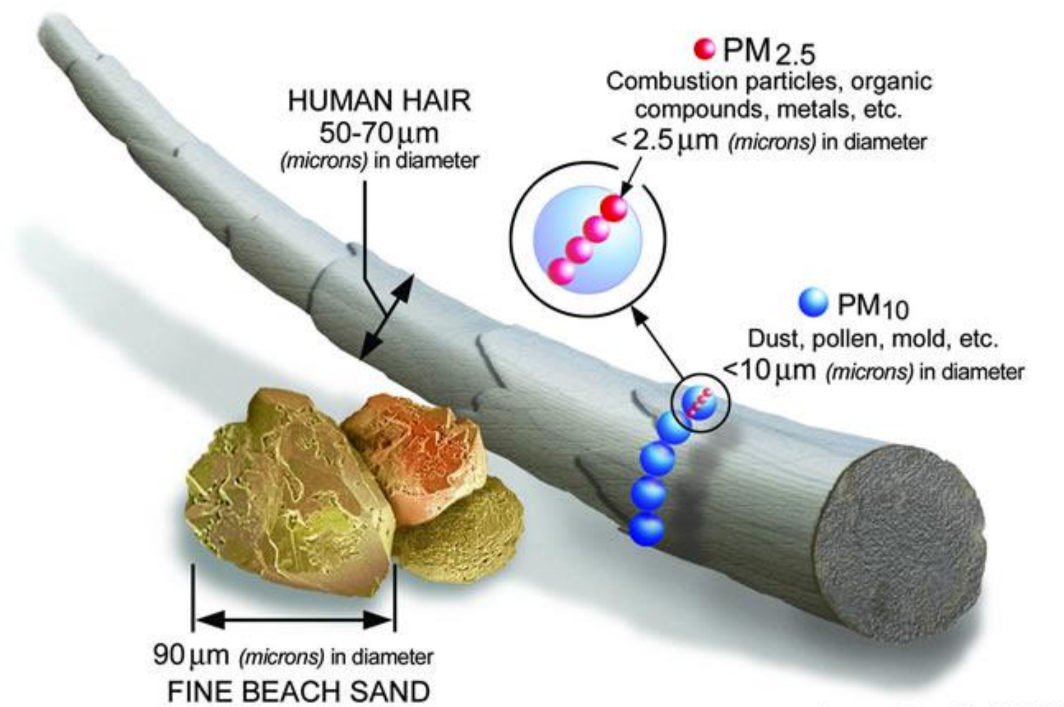
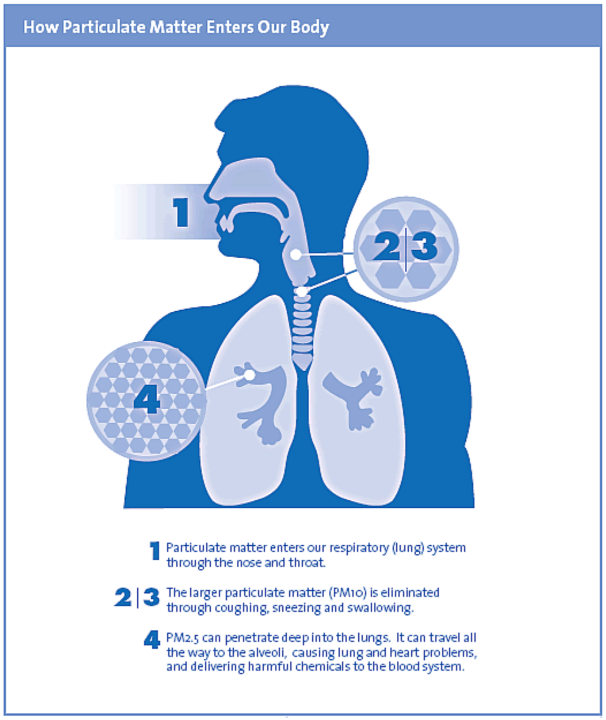


Image courtesy of the U.S. EPA

Particles with diameters less than 10µm are able to pass freely through nasal and oral passages in humans, penetrating deep into the lungs and respiratory system. These particles are often "found near roadways and dusty industries."



In the context of Air Quality, $PM_{2.5}$ represents a very important particle size (It is also an EPA Criteria Pollutant for this reason): it is widely accepted that particles <= 2.5µm pose the greatest threat to human health.

$PM_{2.5}$ particles are often found in smoke and haze emissions from fires, power plants, industrial activities, and automobiles.

The EPA maintains the following website on Particulate Matter:

http://www.epa.gov/ord/ca/quick-finder/particulate-matter.htm

Air Pollution Regulation in the United States

The United States Environmental Protection Agency is responsible for the protection of human and environmental health. Although the organization was formerly created by President Nixon in 1970, legislative efforts to deal with emissions control date back to 1955 with the Air Pollution Control Act.

A comprehensive timeline of EPA history and involvement in pollution control is available at this website:

http://www.epa.gov/history/timeline/index.htm

The amended Clean Air Act establishes what are known as "Criteria Pollutants," which are monitored and regulated by the EPA. They are called "Criteria Pollutants" because they are regulated using "human health-based and/or environmentally-based criteria (science-based guidelines)."

The Clean Air Act legislation is available for download at this address:

http://www.gpo.gov/fdsys/pkg/USCODE-2008-title42/pdf/USCODE-2008-title42-chap85.pdf

The six Criteria Pollutants as defined by the Clean Air Act include:

1. Ozone
2. Particulate Matter (PM)
3. Carbon Monoxide
4. Nitrogen Dioxide
5. Sulfur Dioxide
6. Lead

The EPA maintains a site devoted to information on the six Criteria Pollutants: http://www.epa.gov/oaqps001/urbanair/

Monitoring Techniques

The State of Vermont Department of Environmental Conservation has an excellent website with information on its Air Monitoring equipment and techniques:

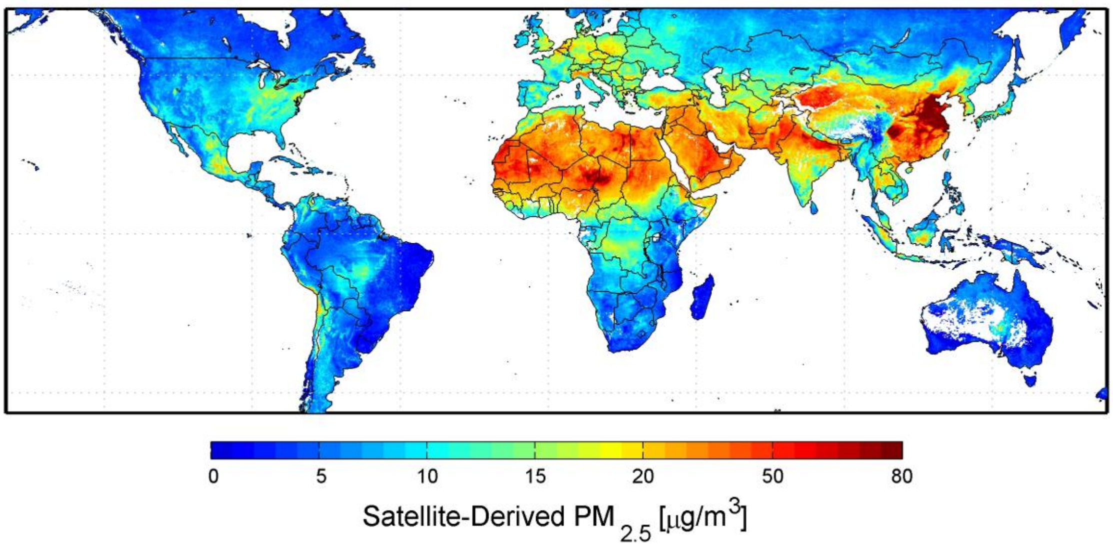
http://www.anr.state.vt.us/air/monitoring/index.htm

There is a detailed breakdown of the individual instruments that are used to measure each of the 6 Criteria Pollutants:

http://www.anr.state.vt.us/air/monitoring/htm/InstrumentInfo.htm

As of 2011, the majority of high precision air quality and pollution monitoring in the United States is done by terrestrial instrumentation. That being said, as digital imagining and satellite instrumentation becomes more and more advanced this monitoring is increasingly being augmented or replaced by space-borne measurements. These technological breakthroughs allow NASA not only to study air quality and pollution in the United States, but perhaps equally importantly, around the world on a massive scale.

This image depicts Particulate Matter (PM) 2.5 as derived from satellite data:



This figure comes from a NASA website detailing the importance of space borne air pollution data collection:

http://www.nasa.gov/topics/earth/features/health-sapping.html

NASA also has a website entitled "How NASA Studies Air" that is part if its "For Kids Only" science program. The site has age appropriate content and activities for explaining how satellites "study" Earth's atmosphere, graphing Atmospheric Ozone, and Air Pressure. (The website is a little bit outdated)