NATS 101
Section 13: Lecture 30

Air Pollution
Part I

How Beijing looked—before the 2008 Olympics….

Economic growth—but at what environmental cost??

China's current industrial development is actually *very similar* to the experience in the U.S. and Europe.

Characteristics

Rapid industrialization and natural resource exploitation, necessary to maintain a high economic growth rate.

Heavy dependence on fossil fuels (coal, oil, natural gas) for the energy supply

Fewer pollution or environmental controls.

Pollution is so bad that it is a major threat to public health and the environment.

London Smog
("Smog" = Smoke + Fog)

Some of the worst events in the last two centuries occurred in London.
1952 Event resulted in 4000 deaths!

<u>Key ingredients</u>: calm winds, fog, smoke particles from coal burning.

Motivated parliament to pass a Clean Air Act in 1956.

The U.S. wasn't doing any better, especially in big industrial cities in the Northeast and Midwest.

Smog in New York City (1963).

Air pollution from burning of coal

Much of the air pollution in the eastern part of the United States was *and is still* due to burning of coal.

Many of the coal plants today are located on or near the Ohio River Why??

Other places with a similar story:

- **Rhine River Valley in Germany**
- **Northern China (Manchuria)**

The U.S. passed its air pollution control act in 1955.

But this act left out one VERY BIG thing!

Pollution from vehicle transportation sources was a rapidly growing problem

But it was a new kind of pollution, different from the traditional smog of London or U.S. eastern cities.

And the worst place for it in America was (and still is) Los Angeles

Pollution controls on vehicles

***Photochemical smog*, was a rapidly growing problem**

This problem was especially prevalent in western U.S. cities, like Los Angeles.

Severe air pollution lead to the Clean Air act of 1970 and the establishment of the EPA.

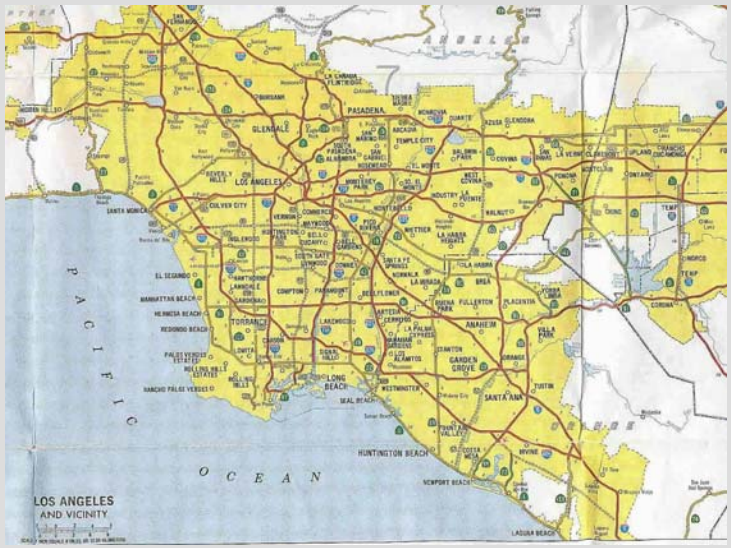
This act and its subsequent additions placed emission control standards on vehicles that each state must meet.

Los Angeles in the 1960s

Even with the Clean Air Act and the EPA, air pollution is still a big problem in the U.S. today.

Reason: ***Though today's cars are less polluting, there are a lot more of them and people drive farther in them than three decades ago.***

You've got to have a car in L.A.



Current L.A. freeway system

"Spaghetti Junction" in L.A.

How did it get this way?

Urban mass transit systems dismantled (i.e. trolley systems)

Freeways built and suburban development followed—along with killer commutes.

Similar story all across the United States…and it still continues today!

What is the environmental consequence?

Photochemical smog
(Los Angeles type smog)

Downtown L.A. on a smoggy day

***Photochemical smog*: Ozone near the ground, caused by chemical reactions involving nitrogen oxides (NO_x) and volatile organic compounds (VOC) in the presence of sunlight.**

What are the health effects of living in this??

But photochemical smog is not unique to Los Angeles, it occurs in every major city in the Southwest U.S.

Arizona is one of THE fastest growing states in America!

Phoenix, Arizona
6th largest city in the U.S.

Maricopa, Arizona
Grew to a population of 40,000 people within just three years!
(Most people who live there drive to the Phoenix area to work…)

NEARLY THE SAME in other western U.S. cities, like Denver, Salt Lake City, Albuquerque, and Las Vegas!

Phoenix, Arizona

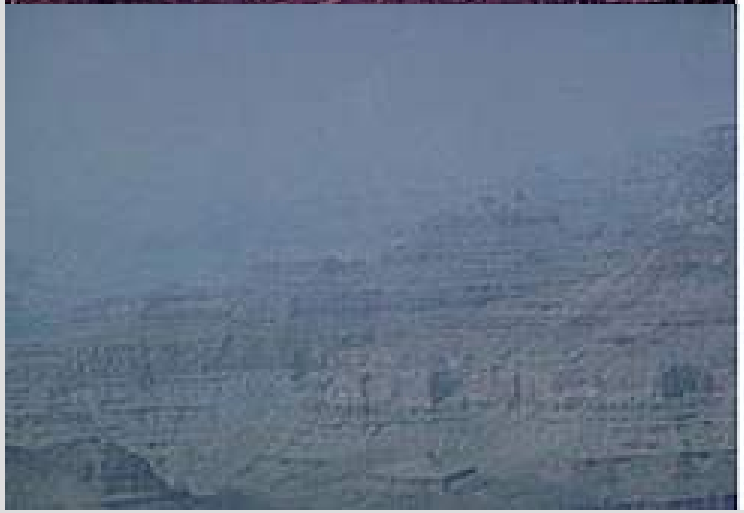
Las Vegas, Nevada

Denver, Colorado

Salt Lake City, Utah

You can’t escape it if you leave the cities either…

Grand Canyon on a clear day.



Grand Canyon on a smoggy day.

http://apollo.lsc.vsc.edu/classes/met130/notes/

Two types of air pollutants

Primary pollutants

Enters the atmosphere directly from (anthropogenic) sources.

THIS IS NASTY STUFF FROM SMOKESTACKS AND TAILPIPES…

Secondary pollutant

Forms as a result of chemical reactions between primary pollutant(s) and/or some other atmospheric constituent.

Examples: photochemical smog and acid rain

Primary Pollutants

Washington, DC in summer.

Particulate Matter

Solid particles and liquid droplets that are small enough to remain suspended in the air

Particles less than 10 microns are more likely they are to get into the lungs and affect the body.

Since hygroscopic, they serve as cloud condensation nuclei.

Resulting wet haze is common in the eastern U.S. in the summertime.

Sulfur Dioxide (SO_2)

Colorless gas that comes primarily from burning of coal and oil.

PARTICULATE MATTER AND SULFUR DIOXIDE ARE THE MAIN CAUSES OF WHAT?

More Primary Pollutants

Carbon monoxide (CO)

Forms by incomplete combustion of carbon-containing fuels. Can be lethal in high concentrations because it replaces oxygen in the blood.

Nitrogen oxides (NO_x)

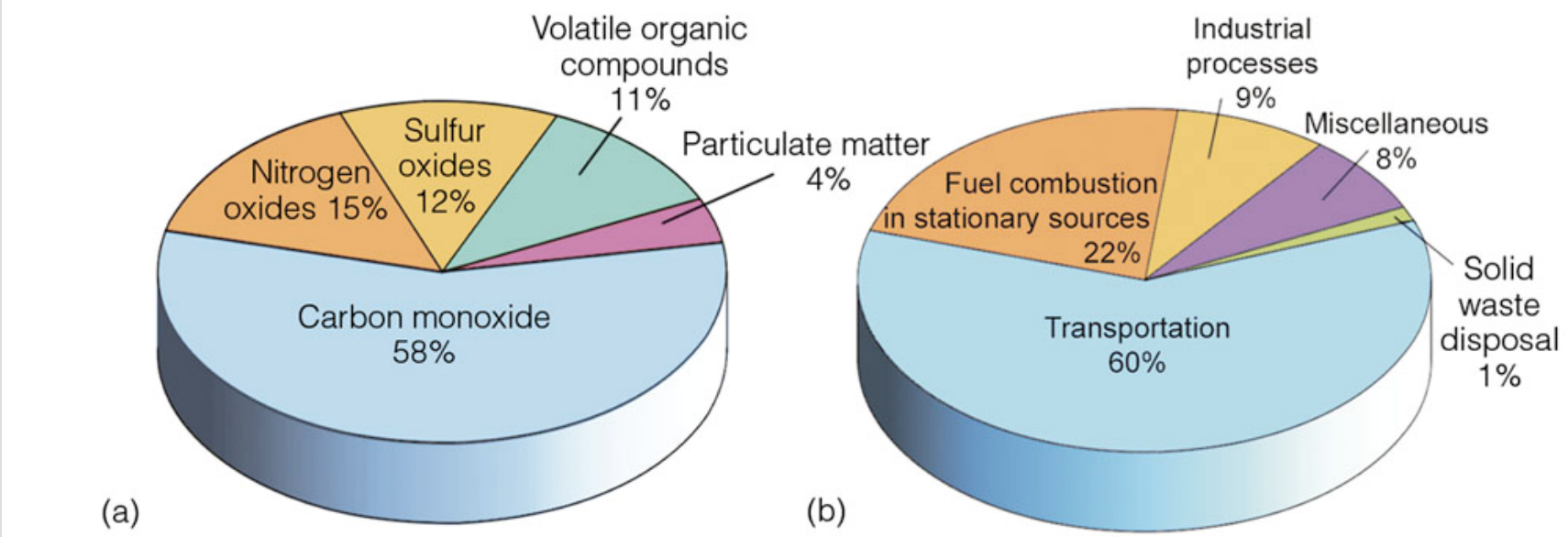
Gases that form when some of the nitrogen in the air reacts with oxygen during fuel combustion process. Can be harmful to respiratory and cardiovascular systems and is carcinogenic.

Volatile organic compounds (VOCs)

Mainly complex hydrocarbon compounds emitted during combustion.

TO CREATE PHOTOCHEMICAL SMOG AS A SECONDARY POLLUTANT NEED NITROGEN OXIDES AND VOLATILE ORGANIC COMPOUNDS.

EPA Estimates of Primary Pollutants and Sources in U.S.



How do nitrogen oxides (NO_x) and volatile organic compounds (VOCs) make photochemical smog?

Formation of photochemical smog

Nitrogen oxide (NO_x) Part:

Photodissociation of NO_2:

NO_2 + sunlight → NO + O

Oxygen radical (O) combines with third molecule (M) to form ozone (O_3):

$O_2 + O + M \rightarrow O_3 + M$

RESPONSIBLE FOR PRODUCING THE OZONE.

Volatile Organic Compound (VOC) Part:

Photodissociation of ozone:

O_3 + sunlight → O_2 + O

Oxygen radical (O) combines with water (H_2O) to form hydroxyl radicals (OH)

$O + H_2O \rightarrow OH + OH$

Hydroxyl radicals react with VOCs (RH), which then removes nitric oxide (NO)

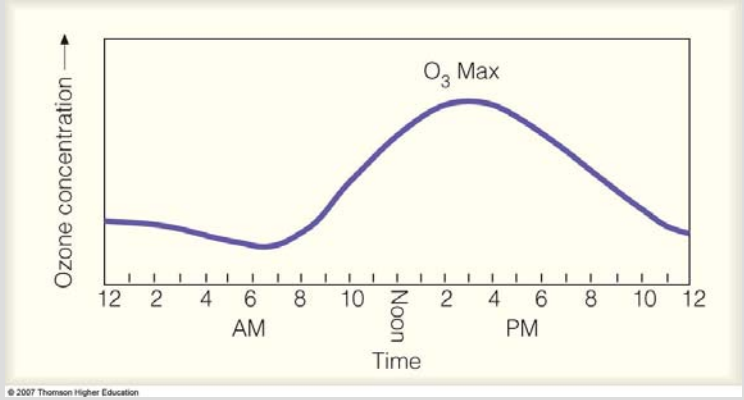
$OH + RH \rightarrow R + H_2O$

$RO_2 + NO \rightarrow NO_2$ + other products.

NITRIC OXIDE CAN REACT WITH VOCs TO FORM NITROGEN DIOXIDE WITHOUT REMOVING OZONE.

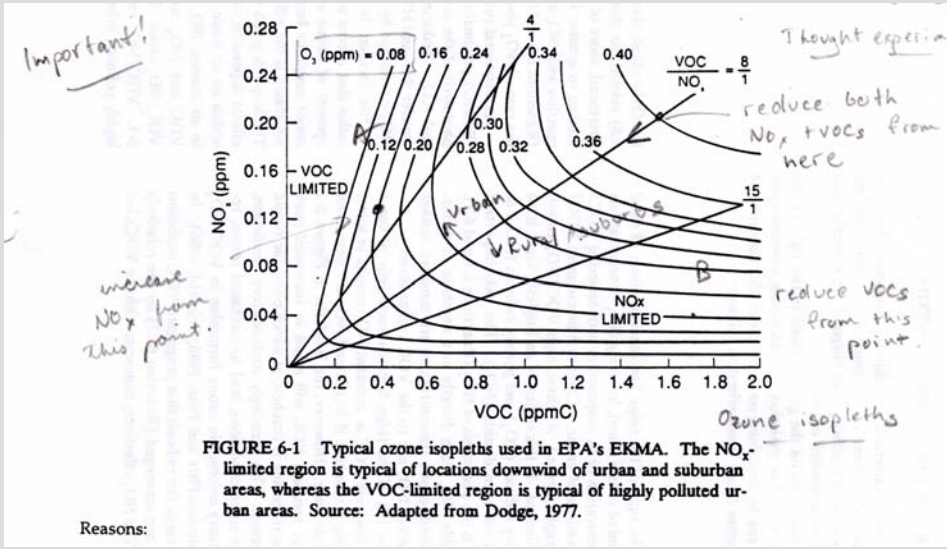
Controls on Production of Photochemical Smog

Control by sunlight



Ozone production maximized in the afternoon
Why??

Control by NO_x and VOCs



Ozone isopleth chart
From my graduate course in atmospheric chemistry (hence the notations)…

Ozone production is either NO_x limited or VOC limited. Ozone production maximized at ratio of VOCs to NO_x = 8:1

Favorable factors for severe air pollution in Southwest U.S.

Big metropolitan areas with a lot of vehicles

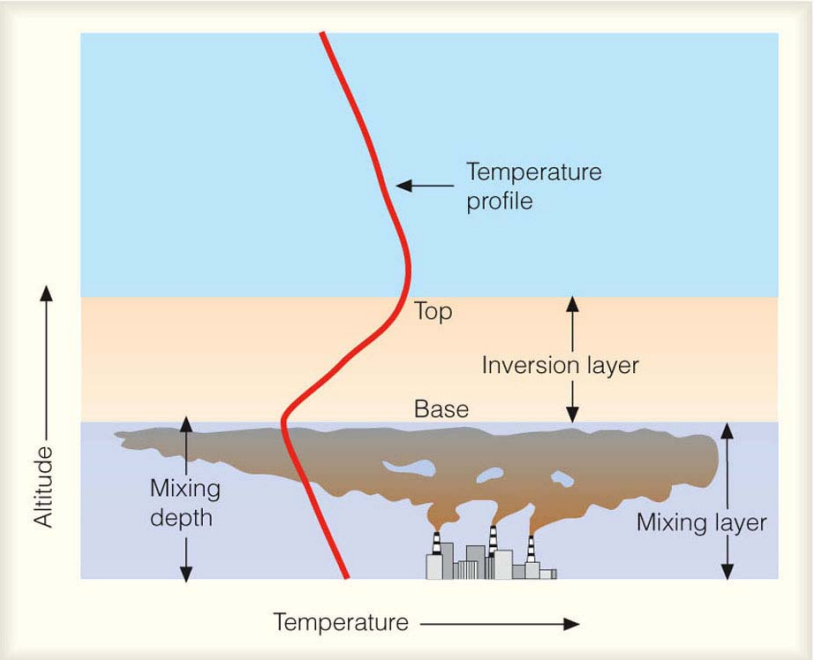
Lots of sunshine

Meteorological conditions that "trap" the air over a metro area for a long time. Most ideal combination:

- **Weak winds**
- **City is located under an inversion.**
- **City is located in a basin or valley surrounded by mountains**

VIRTUALLY ANY MAJOR CITY IN THIS PART OF THE COUNTRY FITS THIS DESCRIPTION WELL SOMETIME DURING THE YEAR!

Meteorological conditions under an inversion



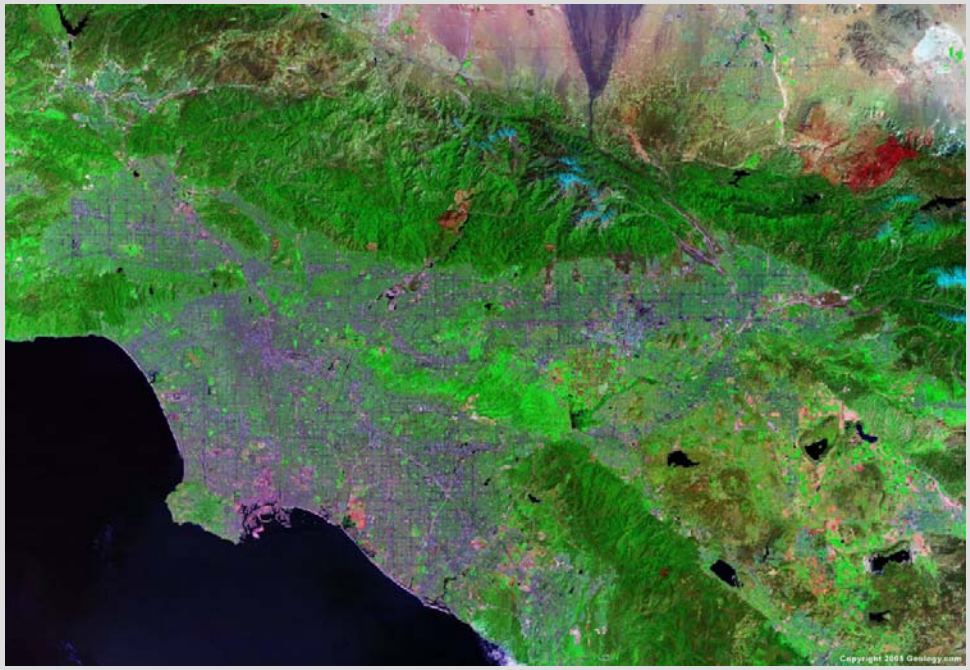
Recall an inversion is when temperature increases with height.

The inversion forms a _____ layer, (like a lid) which prevents the pollutants from escaping.

Pollution spreads out at the top of the inversion.

What meteorological conditions would be conducive for formation of an inversion?

Topographic influence



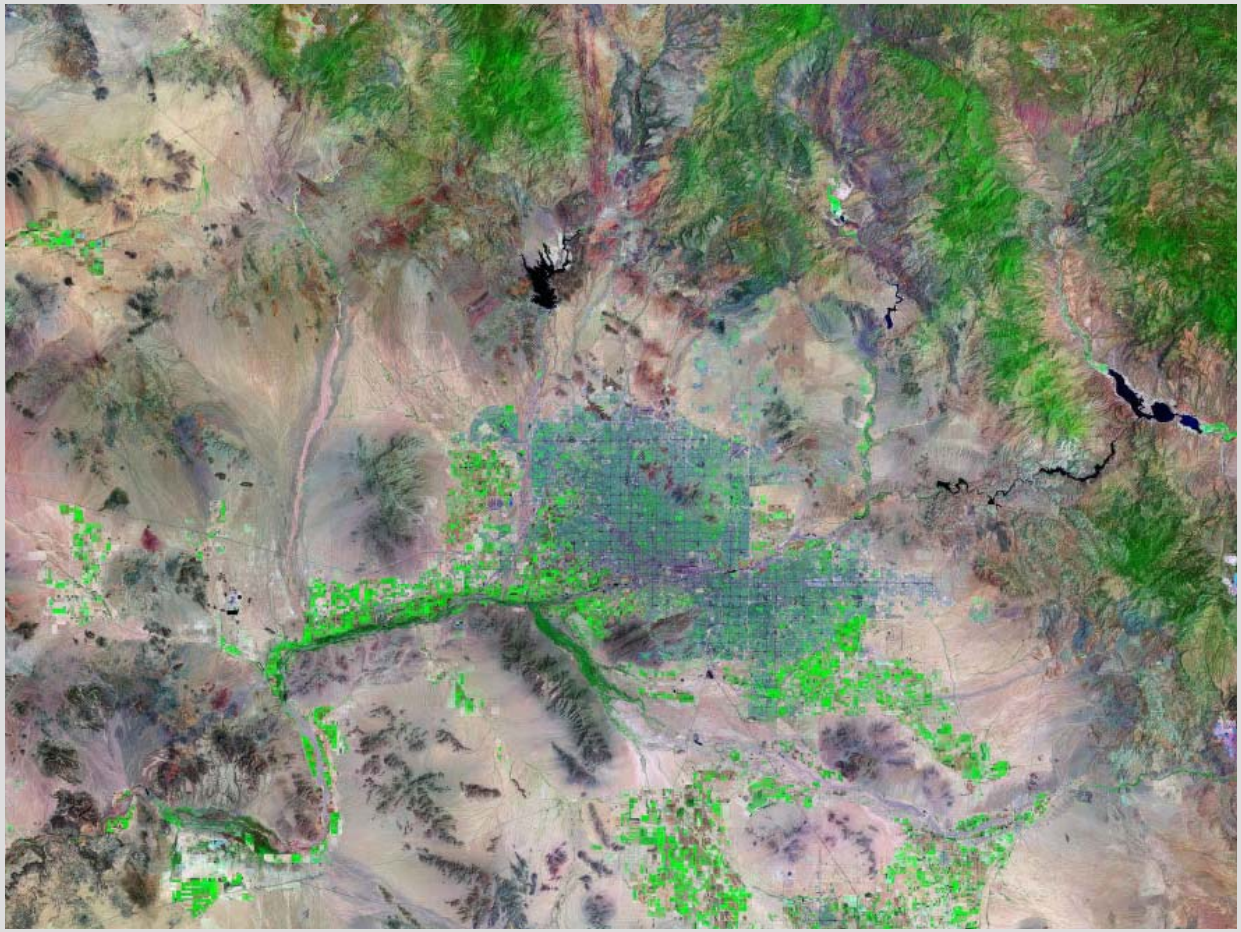
Topography of the L.A. Basin

Los Angeles is located in a basin.

Surrounded on three sides by mountains

When the winds are weak, the mountains are a physical barrier that prevent pollution from escaping.

Phoenix is a LOT like Los Angeles!



Satellite image of Phoenix area.

Smog trapped in a subsidence inversion in a valley.

This is something you would probably see from the mountains looking down at Los Angeles or Phoenix on a sunny and calm day.

But if you think it is bad here, other parts of the world are a WHOLE LOT worse!

Mexico City: THE WORST place for air pollution in North America

Smog in Mexico City

Factors

Located at high elevation surrounded by very high mountains on three sides

A dry and sunny winter under a ridge of high pressure most of the time.

A population of about 9 million people.

Lower environmental standards than U.S.

SIMILAR STORY IN SANTIAGO, CHILE, AND SAO PAULO, BRAZIL

National Air Quality Standards

• TABLE 18.2

The National Ambient Air Quality Standards

POLLUTANT	AVERAGING PERIOD	PRIMARY NAAQS	SECONDARY NAAQS
Ozone (O_3)	1-hour 8-hour	0.12 ppm 0.8 ppm	0.12 ppm 0.8 ppm
Carbon Monoxide (CO)	1-hour 8-hour	35 ppm 9 ppm	— —
Sulfur Dioxide (SO_2)	3-hour 24-hour Annual	— 0.14 ppm 0.030 ppm	0.5 ppm — —
Nitrogen Dioxide (NO_2)	Annual	0.053 ppm	0.053 ppm
Respirable Particulate Matter (10 μm or less) PM 10	24-hour Annual	150 μg/m³ 50 μg/m³	150 μg/m³ 50 μg/m³
Respirable Particulate Matter (2.5 μm or less) PM 2.5	24-hour Annual	65 μg/m³ 15 μg/m³	65 μg/m³ 15 μg/m³
Lead (Pb)	Calendar Quarter	1.5 μg/m³	1.5 μg/m³

These are the federal standards for air pollution measurements.

If the pollution exceeds these standards, then an area is in "non-attainment"

Health Effects of Polluted Air

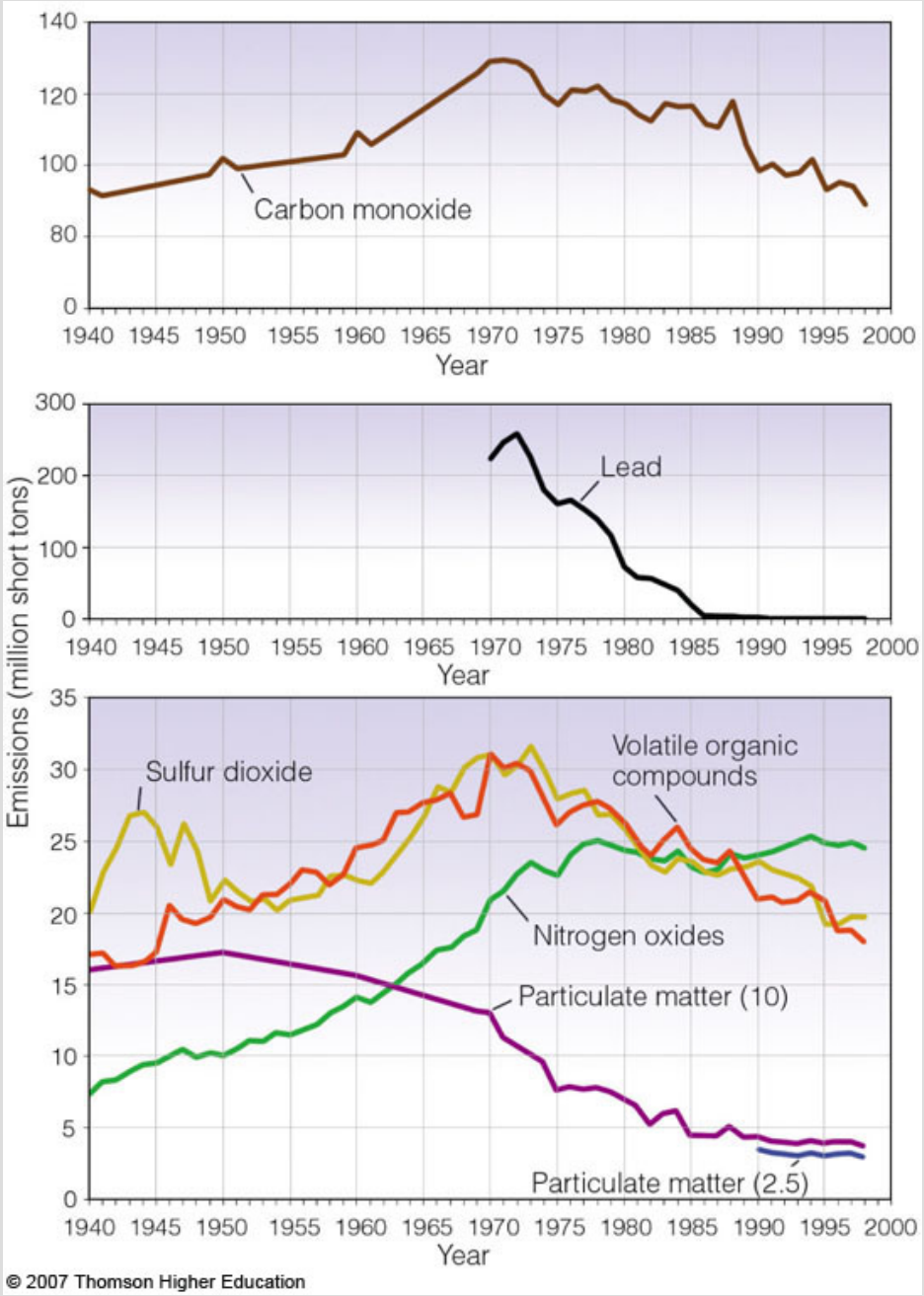
•TABLE 18.3

The Air Quality Index (AQI)

AQI VALUE	AIR QUALITY	GENERAL HEALTH EFFECTS	RECOMMENDED ACTIONS
0-50	Good	None	
51-100	Moderate	There may be a moderate health concern for a very small number of individuals. People unusually sensitive to ozone may experience respiratory symptoms.	When O_3 AQI values are in this range, unusually sensitive people should consider limiting prolonged outdoor exposure.
101-150	Unhealthy for sensitive groups	Mild aggravation of symptoms in susceptible persons.	Active people with respiratory or heart disease should limit prolonged outdoor exertion.
151-200	Unhealthy	Aggravation of symptoms in susceptible persons, with irritation symptoms in the healthy population.	Active children and adults with respiratory or heart disease should avoid extended outdoor activities; everyone else, especially children, should limit prolonged outdoor exertion.
201-300	Very Unhealthy	Significant aggravation of symptoms and decreased exercise tolerance in persons with heart or lung disease, with widespread symptoms in the healthy population.	Active children and adults with existing heart or lung disease should avoid outdoor activities and exertion. Everyone else, especially children, should limit outdoor exertion.
301-500	Hazardous	Significant aggravation of symptoms. Premature onset of certain diseases. Premature death may occur in ill or elderly people. Healthy people may experience a decrease in exercise tolerance.	Everyone should avoid all outdoor exertion and minimize physical outdoor activities. Elderly and persons with existing heart or lung disease should stay indoors.

Our environmental record DOES show some progress in reducing air pollution, but we still have a long way to go.

SO WHAT'S THE SOLUTION??



Summary of Lecture 30

Primary air pollutants include particulate matter, sulfur dioxide, carbon monoxide, nitrogen oxides, and volatile organic compounds. These are largely the result of fuel combustion processes.

London-type smog is caused by particles and sulfur from coal burning. It is more prevalent in the eastern U.S.

Photochemical smog (or L.A.-type smog) is caused by chemical reactions involving nitrogen oxides and volatile organic compounds. It is found in regions with sunny climates since sunlight is necessary for the ozone creation.

Every major city in the Southwest U.S. suffers from a photochemical smog problem because of meteorological conditions that trap air over the metro areas for long periods of time: These include: 1) weak winds;
2) Subsidence inversions, and 3) location in a basin or valley

Air quality standards are defined by the federal government.

Air pollution has numerous negative effects on human health. The air quality index gives a guide for the health effects of pollution and recommended actions.

Review Questions

Reading: **Chapter 18 (cont.)**

Chapter 18 Questions

Questions for Review: 1,5,6,7,8,15,16,17,18,19,21,22

Questions for Thought: 1,3,4,9