Air Pollution

This week we will turn our attention to Air Pollution. I think we all have an idea of what we would could "Air Pollution" but under the Clean Air Act, there is a very specific definition:

Air Pollution: The presence of solids, liquids, or gases in the outdoor air in amounts injurious to humans, animals, plants, or property.

So, we can see from the definition above that the EPA is not only interested in how air pollution affects human health, but also animals, plants, or property. So, hypothetically, if 10 ppm of Carbon Monoxide (CO) was not injurious to humans but damaged plants or property, the EPA may set a standard at that level or lower depending on their analysis. I will focus on primarily human health in this lecture.

As almost all environmental laws (or any laws for that matter), usually trigger events initiated interest:

The 1948 Donora Smog; Donora, Pennsylvania

- inversion layer killed 20 and sickened +7,000
- Donora, Pennsylvania
- Hydrogen Fluoride and Sulfur Dioxide from U.S. Steel Plant
- Temperature inversion October 27th – 31st

So, were the concentrations of Hydrogen Fluoride and/or Sulfur Dioxide much higher on October 27th through the 31st? No! An inversion layer caused the pollutants to get trapped close to the ground. If you recall, the adiabatic lapse rate caused air temperatures to decrease 3.5 degrees F. every 1,000 feet of elevation increase. Thus, usually air closest to the ground is warmer than the air above it. However, inversion layers cause warm air to be on top of cold air……trapping the air and the pollutants in the air near the ground surface.

Great Smog of 1952; London, England

- December 5th – December 9th
- 12,000 dead
- all of London's usual factory emissions plus excessive home burning of coal during a cold spell
- visibility was down to 1 foot in some places

Bhopal India Disaster

- Gas leak at a Union Carbide Pesticide Plant

- over 500,000 exposed to methyl isocyanate gas
- Hundreds of thousands suffered injuries
- Over 5,000 died for sure, could be as high as 15,000

The Clean Air Act focuses on 6 main pollutants which are known as “Criteria Pollutants”:

Criteria Pollutants: SOx, NOx, CO, particulates, lead, and ozone.

I will also talk about hydrocarbons because of their contribution to smog and ozone formation in the Southern California region.

I. Particulates

Are non-gaseous pollutants suspended in air (also called solid and liquid aerosols). Clearly a broad category that includes:

Dust: solids from various physical processes (usually > 1 micron)

Smoke: solids from incomplete combustion (usually < 1 micron)

Fumes: solids from vapor condensation (usually < 1 micron)

Next 2 refer to liquids suspended in air:

Mist: liquids from vapor condensation (generally < 10 microns)

Sprays: liquids from atomization of a parent liquid (> 10 microns)

How do we measure particulates?

1) TSP – Total Suspended Particulate matter (old, outdated)
2) PM-10 – particulate matter (< 10 microns)
3) PM-2.5 – particulate matter (< 2.5 microns)

In general, the smaller the particulate size is the deeper they get into your lungs and, therefore, the greater the health impact.
Sources of Pollutants

II. Sulfur Oxides (SOx):

It’s important to note that there are also natural sources of these criteria pollutants (i.e., criteria pollutants)

III. Monoxide (CO):

- Colorless, odorless, and tasteless
- formed by the incomplete combustion of carbon-containing compounds: it forms when there is not enough oxygen to produce carbon dioxide (CO_2), such as when operating a stove or an internal combustion engine.

IV: Nitrogen Oxides (NOx):

- Nitrogen oxides are produced whenever combustion occurs in the presence of nitrogen – as we see in the L.A. Basin with automobile's exhaust.

V: Lead:

- total lead sources continue to be a major concern even today in the United States, especially close to some manufacturing plants. Prior to the 1970's, lead was added to gasoline so there was a lot more lead pollution in the air.

- Why add lead to gasoline? 1) to increase the octane rating and, 2) to act as a cushion to protect intake and exhaust valves.

IV: Ozone:

- Recently the EPA lowered the federal limit to 70 parts per billion (the previous limit was 75 ppb which was established in 2008).

Smog: "smoke" and "fog" = "smog"

There are two main kinds of smog in the United States:

1) London Smog: "New York Smog" or Gray Smog"

Weather: cool, damp
Content: particulates, sulfur oxides
Sources: coal, etc.

2) L.A. Smog: "photochemical smog" or "brown smog"

Weather: sunny; driven by u.v. energy from the sun
Content: NOx, ozone, hydrocarbons
Sources: gasoline, combustion

Smoggy days

$NO + O_2 \text{ --------} \rightarrow NO_2 + \text{u.v.} \text{ ----------} \cdot O + NO$

$O + O_2 \text{ ----------} \cdot O_3$

$O_3 + NO \text{ -----} \cdot O_2 + NO_2$

$RC + O \text{ -------} \cdot RCO + O_2 \text{ --------} \cdot RCO_3$

$O_2 + RCO_3 \text{ -------} \cdot O_3 + RCO_2$

NO + RCO3 -------▪ NO2 + RCO2

The point here is the cycle repeats itself as you can see: some of the products formed become reactants later and the chain reaction continues – in the presence of sunlight!

Health Effects from Air Pollutants

1) Acute episodes:

Occupational exposures

Acute community episodes

Toxicological studies

Chronic studies

- COPD (chronic obstructive pulmonary disease)

Controls of Air Pollutants

Natural Controls

- Rain: washes out pollutants but can cause acid rain

- Gravity: settles out particulates but can increase exposure at ground level

- Wind: can disperse pollutants but can trap pollutants horizontally

Man-made Controls

Ex: Gas rationing, PCV valves/catalytic converters, treat gas (unleaded), tune-ups, substitute (electric), bicycle

Gasoline and Engines

“Fractional Distillation”:

1) Natural gas
2) Liquefied gas
3) Petroleum ether
4) Aviation gas
5) Auto gas

6) Naphtha

7) Kerosene

8) Fuel Oil

9) Lubricating oils

Processes to increase gasoline:

1) Cracking: breaking down longer chains
2) Polymerization: connecting of smaller chains
3) Alkylation: builds slightly larger chains and helps increase octane rating

Output (from Engines)

"Knocking": ignition at wrong time in an internal combustion engine.

What is "Octane"? A measure of the tendency to produce knocking. 0-100 scale, n-heptane=0; iso-octane=100.

Compression ratio: squeezing the air-fuel mixture during combustion, a higher compression engine increases hp but also increases knocking. So, higher octane needed. This is why high performance sport cars need super unleaded gasoline.

Indoor Air Pollution

Gas stoves to heat apartments/homes

- in just 30 minutes hazardous levels can be reached if fan is not used! Carbon monoxide is a serious issue.

Natural gas central heating

- if properly operating and vented: no problem

- CO monitors very important

Fireplaces (chimney closed): if you burn wood in your fireplace with the chimney closed, toxic levels of CO can accumulate in a very short period of time!

- Recently a couple died in their Jeep after it got stuck in some water and the carbon monoxide from the exhaust filled up the interior of the vehicle. (see article posted this week)

Clean Energy Alternatives: what other sources of energy are out there instead of coal, oil, and fossil fuels in general?

India, China, Brazil, and other developing countries are seeing a massive growth in fossil fuel usage.

- Fossil Fuels: About 86% of world energy use
- Challenge will be moving away from fossil fuels

* USA is only 5% of world population but uses 25% of energy!!!!!!!!

The United States has a severe reliance on Oil: Oil is 39% of total energy use in USA

- 2/3 of oil is imported
- Political stability of other nations is suspect
- Nonrenewable resource so it will eventually run out in a few decades

Natural Gas: Heats 50% of US homes

- Generates 20% of our electricity
- Since 2007 massive reserves discovered in US
- Most experts agree at least 100 years at current demand
- Carbon emissions are 50%
- “Bridge fuel” as we transition to solar/wind/renewable (see video posted)

Energy Challenges: Preserving the planet by cutting carbon emissions

- Enhancing national security by reducing foreign imports
- Avoiding major economic disruption when oil reserves decline
- Energy Efficiency vs Conservation

Efficiency: buying a new refrigerator/light bulbs/weather stripping/etc.
Conservation: Putting on a sweater, raise thermostat

Energy Efficiency

Lighting: 20% of demand, CFL bulbs, LED,
Appliances: “Energy Star”, gas powered vs electric
Home Weatherization Programs: 50% more energy usage in 1939 homes, lots of old homes already built….so these programs are very effective.

Energy Production

- Only 7% of world’s energy production comes from renewable sources
- Most current renewable energy is from hydropower
- Wind, solar, and biofuels are seeing rapid growth in US

Nuclear Power

- No CO_2 emissions
- No Particulates
- No Acid Rain precursors (SOx and NOx)

Rapidly developing nations like China and India are very interested in this type of power. In 2010 there were 58 nuclear plants under construction in 15 countries.

Replacing coal-fired plants with nuclear ones would slash greenhouse gas emissions and combat climate change. However ….. there are some negatives…..just like everything in Environmental Health: we have to balance the positives with the negatives (actually, this applies to all aspects of our lives!)

- Very high construction costs
- Very expensive to run once in operation
- Many years needed to build
- Lack of any permanent disposal sites

So, nuclear will undoubtedly be in the alternative power portfolio but for the reasons explained, it is not the magic bullet. What about:

1) Wind Power

- been around for thousands of years (sailboats/ships)
- 1970s energy crisis increased its use dramatically
- 1980s/1990s saw significant decrease in US while Europe took the lead.
- By 2010 the US was once again the world leader, exceeding 35,000 megawatts.

Negatives of Wind Power:

A) Noise
B) Aesthetics
C) Kill birds/bats

2: Solar Energy

The ultimate in clean, renewable power – limitless.

A) Rooftop Photovoltaic Systems

- First used on space satellites
- most are connected to energy grid via an inverter
- two way flow of energy
- high upfront costs (state/federal tax credits help)

B) Concentrating Solar Power Technologies

- Large, centralized facilities tied into the power grid
- usually mirrors/reflectors concentrate sunlight on a closed vessel containing a liquid, which raises the temp to as high as 750 degrees!
- steam is produced and it powers an electric generator
- worlds largest one is in Barstow, CA

3: Geothermal Energy

In geologically active western states huge potential: cracks in substrata allow steam production from hot water to power a generator.

- steady, uninterrupted energy flow, 24/7
- sometimes water has to be injected eventually so it is not always completely "renewable"

Biofuels

Wind/Solar/Geothermal: little impact on transportation!

- Almost 1 billion vehicles on the global road
- Vehicles use almost 20% of the world's energy

Ethanol, Biodiesel can help reduce our reliance on imported oil (gasoline) but again, they are not the magic bullet either. The point I am trying to make is that there are lots of promising alternatives to traditional gasoline (vehicles) and coal (power plants)….but each alternative has its pluses and minuses. In reality, the future of US energy policy will more than likely include lots of these alternate sources of energy and not just one "magic bullet".