Lecture 2. **What are air pollutants: preliminary review**

Objectives:

1. Air pollution definitions.
2. Air pollution classifications.
3. Major air pollutants: introduction.

Readings: Turco: p. 3-7, 111-112;

1. Air pollution definitions.

Air pollution may be defined as any atmospheric condition in which *substances* are present at concentrations high enough above their normal ambient levels to produce a *measurable effect* on man, animals, vegetation, or materials.

Substances mean any natural or anthropogenic (man-made) chemical compounds capable of being airborne. They may exist in the atmosphere as gases, liquid drops, or solid particles.

Measurable effects on humans and environment due to:

'indoor' air pollutants (Lecture 15),

air toxics, radioactivity (Lecture 16)

urban photochemical smog (Lectures 19-21),

acid rain (Lectures 22-24),

visibility reduction (Lectures 25-26)

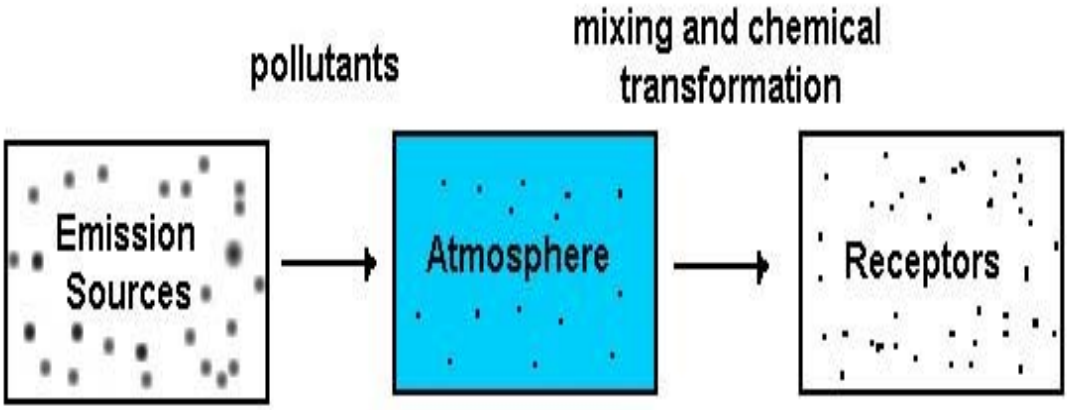
greenhouse warming (Lectures 33-34),

depletion of the ozone layer (Lectures 35-38),

climate forcing due to anthropogenic atmospheric aerosols (Lectures 39-41)

Figure 2.1 An example of air pollution effects.

Figure. 2.2. The air pollution problem can be schematically presented as a system consisting of three basic components:



Major emission sources:

1. Transportation;
2. Industrial and domestic fuel burning;

3. Industrial processes.

Receptors:

1. Humans;
2. Animals;
3. Plans;
4. Materials.

Atmosphere

acts as a medium for transport and dispersion,

physical and chemical transformations

2. Air pollution classification.

according to chemical composition:

1. Sulfur-containing compounds.
2. Nitrogen-containing compounds.
3. Carbon-containing compounds.
4. Halogen-containing compounds.
5. Toxic substances (any of about).
6. Radiative compounds.

according to physical state:

1. Gaseous.
2. Liquid (aqueous).
3. Solid.

according to the manner in which they reach the atmosphere:

1. Primary pollutants (those emitted directly from the sources).
2. Secondary pollutants (those formed in the atmosphere by chemical interactions among primary pollutants and normal atmospheric conditions).

according to the space scales of their effects:

1. Local (or indoor).
2. Regional.

3. Global.

- Criteria air pollutants are six major pollutants defined by EPA (Environmental Protection Agency) for which ambient air standards have been set to protect human health and welfare.

Criteria pollutants (defined by EPA):

1. Ozone, O_3.
2. Carbon monoxide, CO.
3. Sulfur dioxide, SO_2.
4. Nitrogen oxides, NO_x.
5. Lead, Pb.
6. Particulates, PM10.

3. Major air pollutants

Ozone as a pollutant.

Ozone, O3, is a gas.

- At ground level, ozone is a hazard ('bad' ozone) - it is a major constituent of photochemical smog. However, in the stratosphere, it serves to absorb some of the potentially harmful UV radiation from the sun, which is believed to cause skin cancer, among other things ('good' ozone).

Sources: ozone is not emitted into the atmosphere; ozone is formed from the ozone precursors, VOCs, and nitrogen oxides (will be discussed in several Lectures).

"Bad" ozone effects:

- diverse effects on human health
- ecological effects: damage vegetable and trees,

Major sulfur-containing compounds :

Sulfur dioxide, SO_2, is a colorless gas with a sharp odor, primary pollutant, has anthropogenic (man-made) and natural sources.

Anthropogenic sources: industries burning sulfur-containing fossil fuels, ore smelters, oil refineries.

- Sulfur is present in many fuels (e.g., coal, crude oils) over a wide range of concentrations. Combustion causes its oxidation to sulfur dioxide.

Natural sources: marine plankton, sea water, bacteria, plants, volcanic eruption.

SO_2 effects:

- At relatively high concentrations SO_2 causes severe respiratory problems.
- Sulfur dioxide is an acid precursor, which is a source of acid rain produced when SO_2 combines with water droplets to form sulfuric acid, H_2SO_4 (discussed in Lectures 22-24).
- Sulfur dioxide is an precursor of sulfate particulates (sulfates) which affect the radiation balance of the atmosphere and can cause global cooling (discussed in Lecture 39).

Major nitrogen-containing compounds

- Nitrogen, N_2, is a dominant gas of the atmosphere about 78% by volume

(discussed in Lecture 3).

- NO_x stands for an indeterminate mixture of nitric oxide, NO, and nitrogen dioxide, NO_2

Nitrogen oxides, NO_x, are formed mainly from N_2 and O_2 during high-temperature combustion of fuel in cars.

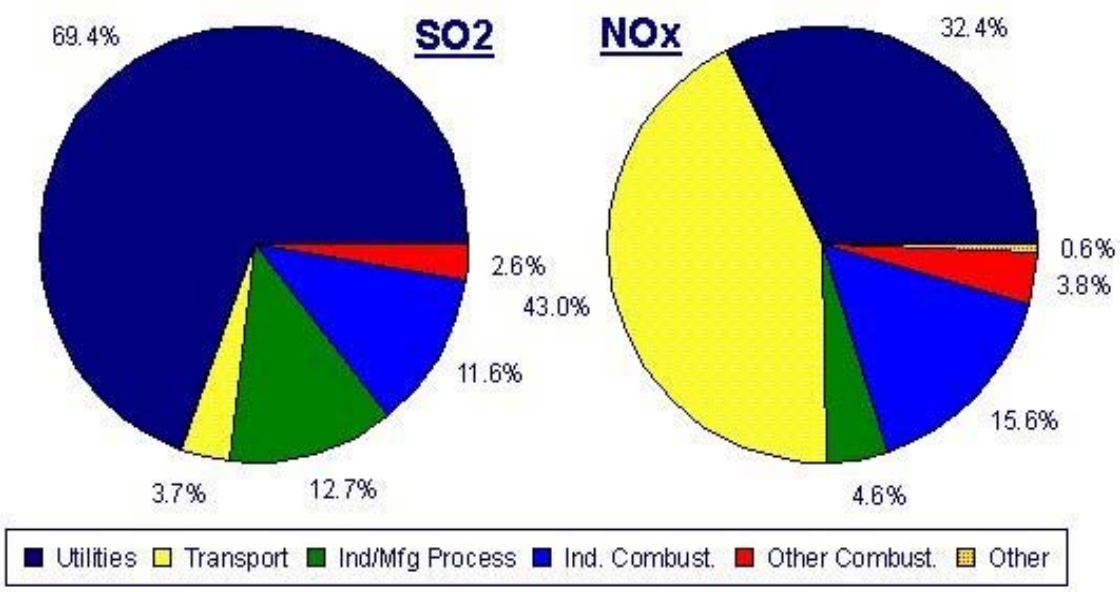
Anthropogenic sources: motor vehicles, biomass burning

Natural sources: bacteria, lightning, biomass burning

NO_x effects:

- causes the reddish-brown haze in city air, which contributes to heart and lung problems and may be carcinogenic
- NO_x is an acid precursor, which is a source of acid rain produced when nitrogen oxides combines with water to produce nitric acid, HNO_3, and other acids (discussed in Lectures 22-24).
- Nitrogen oxides are the precursors of nitrate particulates (nitrates) which affect the radiation balance of the atmosphere and can contribute to global cooling
- Nitrogen oxides are major contributors to the formation of ground level 'bad' ozone.

Figure 2.3 SO_2 and NOx emissions in US (by source)



Major carbon-containing compounds

Carbon monoxide, CO, is a colorless odorless flammable gas, major pollutant of an urban air, produced from incomplete combustion.

Anthropogenic sources: petrol engined motor cars, cigarette smoke, biomass burning

Natural sources: biomass burning

NOTE: CO is also produced by atmospheric oxidation of methane gas and other hydrocarbons.

CO effects:

- CO is highly poisonous to humans and most animals: when inhaled, CO reduces the ability of blood hemoglobin to attach oxygen.

NOTE: Don't confuse carbon monoxide, CO, and carbon dioxide, CO_2. Carbon dioxide is a complete oxidation product of fuel combustion. Also, in the atmosphere, CO oxidized to CO_2.

Carbon dioxide, CO_2, is a key greenhouse gas (discussed in Lectures 33-34)

Principal sources: fossil fuel combustion, deforestation, cement production.

- USA is the single largest emitter of CO_2 accounting for about 16% of the world total.

Hydrocarbons and volatile organic carbons (VOCs):

organic gases are those that contain both hydrogen and carbon, but may also contain other atoms; **hydrocarbons (HCs)** are organic gases that contain only hydrogen and carbon**. Volatile organic compounds (VOCs)** are non-methane hydrocarbons (NMHC) and oxygenated hydrocarbons (which are hydrocarbons plus oxygenated functional groups), (will be discussed in Lecture 8).

Methane, CH_4, is the most abundant hydrocarbon in the atmosphere, found in exhaust gas from automobiles, biomass burning, agriculture activities (e.g., rice paddies).

Anthropogenic sources: indoor sources (e.g., formaldehyde emission), fossil fuel combustion, evaporation of gasoline (e.g., petroleum refineries; during fueling of cars),

Natural sources: HCs produced from decomposition of organic matter; emitted by certain types of plains (e.g., pine trees, creosote bushes)

Effects:

- some HCs are indoor pollutants (e.g., formaldehyde discussed in Lecture 15)
- some HCs and VOCs contribute to ozone-containing smog

Example: pine trees produce VOCs such terpenes responsible for the smell of pines, unfortunately these pleasant VOCs contribute to ozone formation that harms trees.

Major halogen- containing compounds

Chlorofluorocarbons, CFCs, are artificial gases, used as the coolants in refrigerators and air conditioners,; they are neither toxic nor flammable. The most abundant CFCs are CFC-11 (or $CFCl_3$), and CFC-12 (or CF_2Cl_2).

- CFCs are artificial halocarbons, therefor they are not biodegradable. CFCs are not water-soluble, therefore they are not washed from the atmosphere by rain. In the stratosphere, UV radiation destroys CFCs breaking them down to a few chemicals (including atomic chlorine and atomic bromine which efficiently destroy ozone).

CFCs effects:

- they are the key greenhouse compounds (discussed in Lecture 33)
- they lead to reduction of stratospheric "good" ozone (discussed in Lectures 35-38)

Metals as the pollutants.

Metals (such as lead, mercury, cadmium, chromium, nickel) found as impurities in fuels.

Anthropogenic sources: emitted by metal mining and processing facilities; motor vehicle.

Example: lead is a very useful metal, has been mined for thousand of years

Main effect: They are highly toxic (discussed in Lecture 16)

Particulate matters (aerosols) are solid or aqueous particles composed of one or several chemicals and small enough to remain suspended in the air (discussed in several Lectures).

Examples: dust, soot, smoke, sulfates, nitrates, asbestos, pesticides, bioaerosols (e.g., pollen, spores, bacterial cells, fragments of insects, etc.)

PM(10) are particles with diameter < 10 micrometers (μm).

Anthropogenic sources: various (biomass burning, gas to particle conversion; industrial processes; agriculture's activities)

Natural sources: various (sea-salt, dust storm, biomass burning, volcanic debris, gas to particle conversion)

Effects:

- diverse health effects (e.g., harmful to human respiratory system)
- contribute to urban haze, cause visibility reduction (discussed in Lectures 25-26)
- play a key role in the Earth's radiative budget and global change (discussed in Lectures 39-41)

Figure 2.4 Primary pollutant emissions in the United States.