Lecture 1. **What are air pollutants: preliminary review?**

Objectives:

1- Air pollution definitions. 2 - Air pollution classifications.

3- Major air pollutants: introduction.

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.

Meteorology specifies what happen to puff or plume of pollutants from the time it is emitted to the time it is detected at some other location. The motion of the air causes a dilution of air pollutant concentration and we would like to calculate how much dilution occurs as a function of the meteorology or atmospheric condition.

 Air pollutants emitted from anthropogenic sources must first be transported and diluted in the atmosphere before these undergo various physical and photochemical transformations and ultimately reach their receptors. Otherwise, the pollutant concentrations reach dangerous level near the source of emission. Hence, it is important that we understand the natural processes that are responsible for their dispersion. The degree of stability of the atmosphere in turn depends on the rate of change of ambient temperature with altitude.



**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

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* 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, PM**10**.

**Major air pollutants Ozone as a pollutant.**  Ozone, O**3**, 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 isbelieved 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.

"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.

**SO2 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**2**SO**4** .
* Sulfur dioxide is an precursor of sulfate particulates (sulfates) which affect the radiation balance of the atmosphere and can cause global cooling .

**Major nitrogen-containing compounds**

* Nitrogen, N**2**, is a dominant gas of the atmosphere about 78% by volume.
* 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

**NOx 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, HNO3, and other acids.
* 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.

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

**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).

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
* 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 CFC-l3), and CFC-12 (or CF2C-l2).

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
* They lead to reduction of stratospheric "good" ozone

**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 thousands of years. Main effect: They are highly toxic

**Particulate matters (aerosols) are:**

Solid or aqueous particles composed of one or several chemicals and small enough to remain suspended in the air Examples: dust, soot, smoke, sulfates, nitrates, asbestos, pesticides, bio aerosols (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
* play a key role in the Earth’s Radiative budget and global change.

 **CHAPTER FIVE ( )**

**GLOBAL ENVIRONMENTAL PROBLEMS DUE TO AIR POLLUTION**

**5.1. Learning Objective**

After the completion of this chapter, we will be able to:

1- Describe the factors that contribute for global warming

2- Identify the different greenhouse gases.

3- Enumerate the potential adverse health effects of global warming.

4- List different international responses to ozone Depletion.

**5.2. Introduction to the chapter**

The CO2 concentration in the atmosphere is 25% higher than what it was at the beginning of the century. Large scale deforestation, burning of chemical and fossil fuel have created this increase. Climatologists believe that even a small increase atmospheric CO2 can have major effects on climate. CO2 is transparent to incoming visible sun energy, but like glass, it absorbs infrared heat reradiated from the earth's surface. This is called greenhouse effect. The earth planet has already been warmed by 0.8 to 2.5 oC and is going to get hotter by 3 to 5 oC within the next country It is feared that even a slight increase in temperature would cause the polar ice

caps to melt and rise the sea level, submerging a number of major cities of the world, because many are along the seacoast.

**5.3. Global warming**

**What is global warming?**

* The fate of solar energy when reached the earth.
* Absorption by earth and natural greenhouse gases (CO2, CH4, water vapor);
* Infrared radiation reflection by earth’s crust;
* Infrared radiation absorption by the greenhouse gases;
* Infrared radiation [retention](%D8%AD%D8%AC%D8%B2%20%D8%A7%D9%88%20%D8%AD%D8%A8%D8%B3) by greenhouse gases;
* Resulting in an acceptable level of temperature at the earth at 15 0C
* Could have been 19 0C less if the reflected heat from the earth escaped to the space.
* IR absorption by greenhouse gases, as a function of concentration of these gases.

**Anthropogenic (man-made) “greenhouse gases” and their sources:**

1- CO**2**: fossil and bio-mass fuel burning, forest fire, etc.

2- NO**2** : N**2** containing [fertilizers](%D8%A7%D9%84%D8%A7%D8%B3%D9%85%D8%AF%D8%A9) processing, vehicles.

3- CH4: animal [dung](%D8%B1%D9%88%D8%AB) decomposition, [waste landfills](%D9%85%D9%83%D8%A8%20%D8%A7%D9%88%20%D9%85%D9%82%D9%84%D8%A8%20%D8%A7%D9%84%D9%86%D9%81%D8%A7%D9%8A%D8%A7%D8%AA), wet lands, etc

4- CFCs: factories.

5- CO**2** and CFCs are main contributors to IR absorption:

1980 UNEP IR absorption contribution: 55%, 24%, 15% 6% by CO**2**, CFCs, CH**4**, Nitrous oxide, respectively.

**Potential health effects due to global warming General points:**

- Average earth’s temperature variation:

- 0.60C/past 100 years; forecasted: 1-3.50 C/next 100 years

- (an increase of 10C/700 yrs versus today 10C/35 yrs).

- An increase of 20C would result events not seen before 125 000 years ago. Variations in climatically factors: wind velocity, rainfall, etc.

- Variations in the ability to respond to the effects: economics and susceptibility.

**Effects: Direct and Indirect:**

**A/ Direct effects:**

1. Thermal extreme effect: (heat waves) the skin, CNS( Central Nervous System). and [Circulatory system](%D8%A7%D9%84%D8%AF%D9%88%D8%B1%D8%A9%20%D8%A7%D9%84%D8%AF%D9%85%D9%88%D9%8A%D8%A9) the most affected: [thermoregulation disturbance](%D8%A7%D8%B6%D8%B7%D8%B1%D8%A7%D8%A8%20%D8%A7%D9%84%D8%AA%D9%86%D8%B8%D9%8A%D9%85%20%D8%A7%D9%84%D8%AD%D8%B1%D8%A7%D8%B1%D9%8A); [heat stroke](%D8%B6%D8%B1%D8%A8%D8%AA%20%D8%B4%D9%85%D8%B3) and [exhaustion](%D8%A7%D9%84%D8%A7%D8%B1%D9%87%D8%A7%D9%82), decreased male fertility, [cerebro -vascular stroke](%D8%A7%D9%84%D8%B3%D9%83%D8%AA%D9%87%20%D8%A7%D9%84%D8%AF%D9%85%D8%A7%D8%BA%D9%8A%D8%A9), etc.
2. Effect on the respiratory organs: persons with [chronic diseases](%D8%A7%D9%85%D8%B1%D8%A7%D8%B6%20%D9%85%D8%B2%D9%85%D9%86%D8%A9) like [asthma](%D8%A7%D9%84%D8%B1%D8%A8%D9%88), [bronchitis](%D8%A7%D9%84%D8%B4%D8%B9%D8%A8%20%D8%A7%D9%84%D9%87%D9%88%D8%A7%D8%A6%D9%8A%D8%A9), [cardiovascular](%D8%A7%D9%84%D9%82%D9%84%D8%A8%20%D9%88%D8%A7%D9%84%D8%A7%D9%88%D8%B9%D9%8A%D8%A9%20%D8%A7%D9%84%D8%AF%D9%85%D9%88%D9%8A%D8%A9) are the most affected.
3. Weather instability and [natural calamities](%D8%A7%D9%84%D9%83%D9%88%D8%A7%D8%B1%D8%AB%20%D8%A7%D9%84%D8%B7%D8%A8%D9%8A%D8%B9%D9%8A%D8%A9): cyclones, landslides, [draught](%D8%A7%D9%84%D8%A7%D9%86%D9%87%D9%8A%D8%A7%D8%B1%D8%A7%D8%AA), flooding, etc.

**B/ Indirect effects:**

1. [Vector borne diseases](%D8%A7%D9%84%D8%A7%D9%85%D8%B1%D8%A7%D8%B6%20%D8%A7%D9%84%D9%85%D9%86%D9%82%D9%88%D9%84%D8%A9%20%D8%A8%D8%A7%D9%84%D8%AD%D8%B4%D8%B1%D8%A7%D8%AA): mosquitoes (malaria, yellow fever, [rift](%D8%AA%D8%B5%D8%AF%D8%B9) valley fever); Tsetse fly (African sleeping sickness); Fly (faecooral related diseases, [onchocerciasis](%D8%AF%D8%A7%D8%A1%20%D9%83%D9%84%D8%A7%D8%A8%D9%8A%D8%A9%20%D8%A7%D9%84%D8%B0%D8%A6%D8%A8), [leishmaniasis](%D8%A7%D9%84%D9%84%D8%B4%D9%85%D8%A7%D9%86%D9%8A%D8%A7), [schistosomiasis](%D8%A7%D9%84%D8%A8%D9%84%D9%87%D8%A7%D8%B1%D8%B2%D9%8A%D8%A7).)
2. [Waterborne diseases](%D8%A7%D9%84%D8%A7%D9%85%D8%B1%D8%A7%D8%B6%D8%A7%D9%84%D9%85%D9%86%D9%82%D9%88%D9%84%D8%A9%20%D8%A8%D8%A7%D9%84%D9%85%D8%A7%D8%A1): due to water [shortage](%D9%86%D9%82%D8%B5) & [contamination](%D8%AA%D9%84%D9%88%D8%AB).
3. Sea-level rise: damages fresh water, affects soil salinity,
4. Agricultural productivity:
* Reduced rainfall; increased [pests](%D8%A7%D9%84%D8%A7%D9%88%D8%A8%D8%A6%D8%A9); decreased soil fertility; decreased farming land, etc.
* Affects both [staple foods](%D8%A7%D9%84%D8%A7%D8%BA%D8%B0%D9%8A%D8%A9%20%D8%A7%D9%84%D8%A7%D8%B3%D8%A7%D8%B3%D9%8A%D8%A9) & [horticulture harvesting](%D8%AD%D8%B5%D8%A7%D8%AF%20%D8%A7%D9%84%D8%A8%D8%B3%D8%AA%D9%86%D8%A9); and animal [husbandry](%D8%AA%D8%B1%D8%A8%D9%8A%D8%A9).
* Food shortages and [malnutrition](%D8%B3%D8%A4%20%D8%A7%D9%84%D8%AA%D8%BA%D8%B0%D9%8A%D8%A9);
1. Air pollution impact: increased pollen; concentration of pollutants;
2. Impacts to socio-economic development.

**5.4. OZONE DEPLETION**

**Identity**: found in stratosphere in nature as O3; its detection in troposphere (ground level) is an indicator of pollution.

**Its role**:

* Solar radiation: 55% IR; 40% visible light; 5% UV.
* Acts as a UV protective blanket (layer).
* UV radiation includes three bands: UVA (400-320nm); UVB (320-280nm); UVC (280-200nm), far UV (< 50nm).
* It blocks nearly all UVC, half UVB, and small part UVC.

**Mechanism for UV blocking:**

􀂾 Equilibrium in nature between destruction and production of O**3**.

􀂾 O**2** → O+O (energized by UVC)

􀂾 10+O**2**→ O**3** + IR (production of Ozone)

􀂾 O**3** + UV → O2+O: (destruction of Ozone as energized by UVB)

**What causes Ozone depletion?**

**•** Human activity: release of halogenated hydrocarbons: CFCs; CCI4;

**•** Are used as refrigerants, propellants, solvents, foam production, etc.

**•** Are stable under normal conditions in the troposphere.

**•** These volatile chemicals become active with the presence of UV to react with O3;

**The reaction:**

1. CCI**2**F**2** + UV → CCIF**2** + CI-

2. CI- + O**3** → CIO + O**2**

3. CIO +O→ CI- + O**2**

4. Net: O**3**+O→2O**2** (Chlorine atom acts as a catalyst).

**Potential adverse effects:**

* + UVC is absorbed by O3, (does not reach the earth);
	+ UVB and UVA reach the earth.