Environmental Engineering – Module 3: Air Quality and Air Pollution

1. Composition and Properties of Air

- **Composition of Dry Air (by volume):**
  - Nitrogen (N_2): 78.09%
  - Oxygen (O_2): 20.95%
  - Argon (Ar): 0.93%
  - Carbon dioxide (CO_2): 0.03%
  - Trace gases: Neon, Helium, Methane, Krypton, Hydrogen, Ozone, etc.
- **Properties:**
  - Air density, viscosity, temperature and humidity affect dispersion of pollutants.
  - Atmospheric pressure and temperature vary with altitude.
  - Air acts as a medium for combustion and supports life.

2. Quantification of Air Pollutants

- **Common Air Pollutants:**
  - Particulate Matter (PM_{10} and $PM_{2.5}$)
  - Sulfur dioxide (SO_2)
  - Nitrogen oxides (NOx)
  - Carbon monoxide (CO)
  - Ozone (O_3)
  - Volatile organic compounds (VOCs)
  - Lead (Pb) and other heavy metals
- **Units of measurement:**
  - Concentrations typically expressed in micrograms per cubic meter ($\mu g/m^3$) or parts per million (ppm).
  - Emission rate: mass per unit time (e.g., kg/hr).
- **Pollutant Quantification Methods:**
  - Emission inventories based on fuel consumption and industrial processes.
  - Calculation based on source characteristics using emission factors.

3. Monitoring of Air Pollutants

- **Purpose:** To assess pollution levels, sources, and compliance with air quality standards.
- **Types of Monitoring:**
  - **Ambient Air Monitoring:** Measures pollutants in outdoor air.
  - **Stack Monitoring:** Measures emissions from point sources like chimneys.
- **Common Monitoring Techniques:**
  - **Gravimetric analysis** for particulate matter.
  - **Gas analyzers** using chemical or instrumental methods for gaseous pollutants (e.g., SO_2 by West-Gaeke or Pararosaniline method, NOx by Chemiluminescence analyzer).
  - Continuous Ambient Air Quality Monitoring Stations (CAAQMS) equipped with real-time analyzers.
  - Remote sensing and air quality sensors.

4. Air Pollution – Occupational Hazards

- Workers in industries such as mining, construction, chemical manufacturing, and metal refining face risks due to exposure to dust, toxic gases, and vapors.
- Common hazards:
  - Respiratory diseases (silicosis, asbestosis, pneumoconiosis)
  - Chemical poisoning (lead, mercury, benzene)
  - Noise and heat stress
- Prevention includes proper ventilation, personal protective equipment (PPE), and workplace exposure limits.

5. Urban Air Pollution and Automobile Pollution

- **Urban Air Pollution Sources:**
  - Vehicular emissions (major source in cities).
  - Industrial emissions.
  - Construction dust.
  - Domestic fuel combustion.
- **Automobile Pollution:**
  - Emission of CO, NOx, hydrocarbons (HC), particulate matter.
  - Types of engines:
    - Spark Ignition (SI) engines (gasoline)
    - Compression Ignition (CI) engines (diesel)
  - Emission depends on combustion efficiency, fuel quality, engine type, and operating conditions.

6. Chemistry of Combustion

- **Complete combustion:** Hydrocarbon fuels react with oxygen to produce CO_2 and H_2O.
$$C_xH_y + O_2 \rightarrow CO_2 + H_2O + Energy$$
- **Incomplete combustion:** Produces CO, unburned hydrocarbons, soot, and other pollutants.
- Poor combustion leads to higher emissions and loss of energy.

7. Automobile Engines, Fuel Quality, Operating Conditions, and Interrelationships

- **Engines:**
  - SI engines operate with spark ignition, lean fuel-air ratio to reduce emissions.
  - CI engines operate with compression ignition, tend to emit more particulates and NOx.
- **Fuel Quality:**
  - Octane number for petrol.
  - Cetane number for diesel.
  - Presence of sulfur affects SO_2 emissions and catalyst poisoning.
- **Operating Conditions:**
  - Engine load, speed, maintenance, and temperature affect emission levels.
  - Cold starts and idling increase pollutant emissions.
  - Fuel injection methods also influence combustion efficiency.
- **Interrelationship:**
  - Fuel type and quality affect combustion chemistry and emission composition.
  - Operating parameters influence fuel consumption and pollutant formation.

8. Air Quality Standards

- Established by national and international agencies (e.g., Central Pollution Control Board (CPCB), WHO).
- Specify maximum allowable concentrations for pollutants to protect human health and the environment.
- Examples of Indian Ambient Air Quality Standards (Annual/24-hour values):

Pollutant	Standard (µg/m³)
PM10	100 (24-hr), 60 (annual)
PM2.5	60 (24-hr), 40 (annual)
SO_2	80 (24-hr), 50 (annual)
NO_2	80 (24-hr), 40 (annual)
CO	4 mg/m³ (8 hr)
O_3	100 (8 hr)

9. Control Measures for Air Pollution

- **Source Control:**
  - Use of cleaner fuels.
  - Improved combustion techniques.
  - Industrial process modification.
- **Emission Control Devices:**
  - Electrostatic precipitators (ESP) for particulates.
  - Cyclone separators.
  - Scrubbers (wet and dry) for SO_2 removal.
  - Fabric filters (baghouses).
  - Catalytic converters in vehicles.
- **Urban Planning:**
  - Zoning to separate industrial areas.
  - Promotion of public transport.
  - Green belts and urban forestry.
- **Limitations:**
  - High capital and operational costs.
  - Effectiveness depends on maintenance.
  - Some technologies generate secondary wastes.

If you'd like, I can provide detailed explanations, formulas, design methods, or case studies related to any of these topics. Let me know!