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Unit-II

Sampling and analysis of air pollutant

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Sampling in Air Pollution

- Sampling is a critical step in assessing air quality and understanding the presence and concentration of pollutants in the atmosphere. It involves collecting a representative portion of air to analyze for specific contaminants. Proper sampling ensures accurate, reliable data for regulatory, research, or health purposes.

- Classification of Sampling Methods
- Air sampling methods can be broadly classified based on:
- *1. Sampling Techniques:*
- **Grab Sampling:**
  - A single sample of air is collected over a short period.
  - Suitable for determining instantaneous pollutant levels.
  - Example: Sampling during a short-term industrial process release.
- **Integrated Sampling:**
  - Air is collected over a longer period (e.g., hours to days).
  - Provides average pollutant concentrations over time.
  - Example: Monitoring daily ambient air quality.
- **Continuous Sampling:**
  - Real-time monitoring of air pollutants using automated instruments.
  - Provides detailed time-series data for dynamic pollutants.
  - Example: Use of sensors in urban air quality monitoring.

- *2. Sampling Locations:*
- **Ambient Air Sampling:** Measurement of pollutants in the general atmosphere.
- **Indoor Air Sampling:** Assessment of pollutants within buildings.
- **Source Sampling:** Collection of emissions directly from a source, like chimneys or exhausts.

- *3. Sampling Media:*
- **Active Sampling:** Requires external power to draw air through a filter or sorbent.
  - Example: High-volume air samplers.
- **Passive Sampling:** Relies on diffusion or permeation of air pollutants.
  - Example: Diffusion tubes.

- *4. Pollutant Types:*
- **Particulate Sampling:** Collection of particles like PM2.5, PM10 using filters or cyclones.
- **Gas Sampling:** Collection of gases like NOx, SO2, CO using impingers or adsorption tubes.

- Difficulties Encountered in Air Sampling
- **Representative Sampling:**
  - Capturing a true representation of air quality in dynamic environments is challenging.
- **Environmental Interference:**
  - Temperature, humidity, and wind can affect pollutant concentrations and sampling efficiency.
- **Instrument Calibration and Maintenance:**
  - Instruments need regular calibration to ensure accuracy. Poor maintenance can lead to errors.
- **Handling and Storage:**
  - Contamination during sample transportation or storage can alter pollutant levels.
- **Low Pollutant Concentrations:**
  - Detecting and quantifying pollutants present in minute concentrations is technically demanding.
- **Regulatory Compliance:**
  - Adhering to standard protocols and guidelines can be complex.
- **Cost and Logistics:**
  - Sophisticated equipment and trained personnel add to the cost and operational challenges.

- Basic Considerations for Air Sampling
- **Purpose of Sampling:**
  - Define objectives, e.g., compliance, research, or source identification.
- **Selection of Pollutants:**
  - Identify key pollutants based on the study area and sources (e.g., industrial emissions, vehicular exhaust).
- **Sampling Location:**
  - Choose locations representative of the area or specific to sources (urban, rural, industrial zones).
- **Sampling Time:**
  - Determine time intervals based on diurnal variations, weather conditions, and pollutant sources.
- **Sampling Techniques and Equipment:**
  - Select appropriate methods and instruments based on pollutant type, concentration, and regulatory standards.
- **Quality Assurance:**
  - Employ quality control measures like calibration, duplicate sampling, and data validation.
- **Data Interpretation:**
  - Ensure proper statistical tools and models are used for meaningful insights from collected data.
- **Health and Safety:**
  - Follow safety protocols for personnel involved in hazardous air sampling environments.

Instruments for Air Sampling

- Air sampling instruments are critical tools for measuring and analyzing air pollutants. They include specialized devices designed to collect, quantify, and analyze particulate matter, gases, and vapors in the atmosphere. These instruments are broadly categorized into meters, probes, suction devices, and other general devices based on their application and functionality.

- 1. Meters, Probes, and Suction Devices
- *Meters:*
- Meters are used for real-time measurement and analysis of air pollutants. They provide instantaneous data and are often employed in continuous air monitoring.
- **Gas Detectors:**
  - Used for detecting specific gases like CO, SO_2, NOx, and O_3.
  - Example: Electrochemical gas meters for CO detection.
- **Particulate Matter Monitors:**
  - Measure concentrations of PM2.5 and PM10 using laser scattering or beta attenuation.
  - Example: Optical particle counters.
- **Ozone Meters:**
  - Use ultraviolet (UV) photometry to measure ozone concentrations in the air.

- *Probes:*
- Probes are used to extract air samples from specific locations or environments. They are particularly useful for source sampling or monitoring specific areas like industrial exhausts.
- **Sampling Probes:**
  - Stainless steel or Teflon-coated probes are used to avoid chemical reactions with pollutants.
  - Example: Stack sampling probes for monitoring emissions from chimneys.
- **Pitot Tubes:**
  - Measure air velocity in ducts or stacks, critical for calculating pollutant flux.

- *Suction Devices:*
- Suction devices draw air samples through filters, adsorbents, or other collection media for subsequent analysis.
- **High-Volume Samplers:**
  - Used for collecting particulate matter over extended periods.
  - Example: Devices that use pumps to draw large volumes of air through filters.
- **Low-Volume Samplers:**
  - Used for localized sampling or when pollutant concentrations are low.
  - Example: Mini pumps for passive air sampling.

- 2. General Devices
- *Active Sampling Devices:*
- These require external power to draw air through collection media like filters or adsorbents.
- **Filtration Systems:**
    - Air is drawn through filters that trap particulate matter for analysis.
    - Example: Glass fiber filters for PM10 sampling.
- **Impingers:**
    - Air is bubbled through liquid reagents to capture gaseous pollutants like SO_2 and NH_3.
- *Passive Sampling Devices:*
- These rely on natural diffusion or permeation of air pollutants.
- **Diffusion Tubes:**
    - Contain sorbent material to trap gases like NOx and SO_2.
    - Suitable for long-term monitoring in ambient air.
- **Badges:**
    - Lightweight devices worn by individuals to monitor personal exposure to pollutants.

- 3. Devices for Gases and Vapors
- *Gas Sampling Devices:*
- Specialized instruments for collecting and analyzing gaseous pollutants.
- **Canisters:**
  - Stainless steel containers used for grab sampling of volatile organic compounds (VOCs).
  - Example: SUMMA canisters for hydrocarbon analysis.
- **Adsorption Tubes:**
  - Filled with materials like activated charcoal or silica gel to adsorb specific gases.
  - Commonly used for VOC sampling.
- *Vapor Sampling Devices:*
- Vapors are collected using techniques that account for their tendency to condense or react.
- **Cryogenic Traps:**
  - Use low temperatures to condense and collect vapors.
  - Suitable for organic compounds and mercury vapor.
- **Denuder Systems:**
  - Remove gases selectively while allowing particulate matter to pass.
  - Example: Used in ammonia and acid vapor sampling.

- 4. Instrumentation Considerations
- **Sensitivity and Accuracy:**
  - Instruments should detect pollutants at required concentrations with minimal error.
- **Portability:**
  - Compact and lightweight devices are preferred for field applications.
- **Durability:**
  - Devices should withstand harsh environmental conditions.
- **Ease of Calibration and Maintenance:**
  - Regular calibration is essential for accuracy; instruments should be easy to maintain.
- **Compatibility with Pollutants:**
  - Materials used in the instruments should not react with the sampled pollutants.

Various Sampling Instruments and Methods

- Sampling air pollutants involves the use of specialized devices and methods to capture, measure, and analyze gases, vapors, and particulates. Below is an in-depth discussion of key instruments and methods used for air sampling and analysis.

1. Absorbers

- Absorbers are used to remove gaseous pollutants from the air by dissolving them into a liquid medium.
- Working Principle:
  Gases pass through a liquid (e.g., water, alkali solutions) where the target gas dissolves or reacts chemically.
- Examples:
  - Packed towers: Contain materials to increase gas-liquid contact area.
  - Spray towers: Use liquid sprays to absorb pollutants like SO_2 and NH_3.

2. Adsorbers

- Adsorbers trap gaseous pollutants on the surface of a solid material through physical or chemical adsorption.
- Working Principle:
  Gases adhere to the surface of porous materials like activated carbon or silica gel.
- Applications:
  - Sampling volatile organic compounds (VOCs).
  - Capturing hydrocarbons and other odorous compounds.

- **3. Condensers**
- Condensers are used to cool and condense vapors into liquids for collection and analysis.
- Types:
  - Shell-and-tube condensers: Use coolants to lower the temperature.
  - Air-cooled condensers: Use ambient air for cooling.
- Applications:
  - Sampling water vapor or volatile compounds.
  - Common in industrial stack sampling.

- **4. Collectors**
- Collectors are used to capture particulate matter (PM) from the air.
- Types:
  - Filters: Capture particles based on size.
  - Cyclones: Use centrifugal force to separate particles.
- Examples:
  - PM10 or PM2.5 filters.
  - Baghouse filters in industrial plants.

- **5. Plastic Containers**
- Plastic containers are used for storing and transporting air samples.
- Features:
  - Non-reactive materials like PTFE or HDPE to prevent contamination.
  - Airtight seals to preserve sample integrity.
- Applications:
  - Transporting gas samples or adsorbent tubes.
  - Collecting liquid samples from impingers.

- **6. Samplers for Mass Spectrometric Analysis**
- Mass spectrometry (MS) requires precise sample collection for analyzing complex mixtures of pollutants.
- Sampling Devices:
  - Adsorption Tubes: For VOCs; desorbed during MS analysis.
  - Canisters: For capturing gaseous samples like methane.
  - Direct Injection Probes: For immediate analysis of air samples.

Sampling Methods

- ***(a) Sedimentation:***
- Particles settle under gravity onto collection plates.
- Advantages:
  - Simple and cost-effective.
- Limitations:
  - Ineffective for small particles (<10 µm).

- ***(b) Filtration:***
- Air is passed through filters to trap particulates.
- Materials:
  - Glass fiber, cellulose, or polymer filters.
- Applications:
  - Collecting PM2.5 or PM10 for gravimetric analysis.

- ***c) Impingement:***
- Air is bubbled through a liquid medium that traps pollutants.
- Examples:
  - SO_2 absorption in sodium tetrachloromercurate solution.
- Applications:
  - Monitoring gaseous pollutants like NH_3 and H_2S.
- ***(d) Electrostatic Precipitators (ESPs):***
- Use electric fields to charge and collect particulate matter.
- Working Principle:
  - Particles acquire a charge and are attracted to collection plates of opposite charge.
- Applications:
  - High-efficiency collection of fine particulates in industrial emissions.
- ***(e) Thermal Precipitation:***
- Particles are deposited on surfaces due to temperature gradients.
- Mechanism:
  - Hot particles move toward cooler surfaces where they condense.
- Applications:
  - Sampling soot and aerosols.

- ***(f) Centrifugal Methods:***
- Use centrifugal force to separate particulates from air.
- Devices:
  - Cyclones: Air rotates inside a chamber, separating heavier particles.
- Applications:
  - Industrial dust collection and source emissions.

- ***(g) Solution Impingers:***
- Gaseous pollutants are captured in a liquid solution.
- Mechanism:
  - Air passes through a bubbling liquid that absorbs the pollutants.
- Examples:
  - Acidic solutions for ammonia.
  - Alkaline solutions for acidic gases like SO_2.

Sampling and Analysis for Suspended Particulates

- Sampling and analysis of suspended particulates are critical for assessing air quality, understanding pollutant sources, and determining their impact on health and the environment. This note provides insights into sampling techniques and various analysis methods.

- **1. Sampling for Suspended Particulates**
- ***(a) High-Volume Sampler (HVS):***
- The high-volume sampler is a commonly used device for collecting suspended particulates like PM10 and PM2.5.
- Working Principle:
  - A pump draws a large volume of air through a filter (e.g., glass fiber filter).
  - Particulates are trapped on the filter, and their mass is determined gravimetrically.
- Features:
  - Typically operates for 24 hours to provide daily average concentrations.
  - Suitable for ambient air sampling.
- Applications:
  - Regulatory compliance for air quality standards.
  - Source identification of particulates.
- ***(b) Stack Sampling Techniques:***
- Stack sampling is used to measure emissions directly from industrial stacks or chimneys.
- Methods:
  - Isokinetic Sampling: Ensures that the velocity of the sampled gas matches the stack velocity to avoid particle bias.
  - Impingers: Collect particulates and gases simultaneously in a liquid medium.
  - Cyclones or Filters: Trap particles based on their size and density.
- Applications:
  - Monitoring industrial emissions for compliance.
  - Assessing pollutant dispersion from point sources.

- **2. Analysis Methods for Suspended Particulates**
- ***(a) Chemical Analysis:***
- Determines the composition of particulate matter, including metals, organic compounds, and ions.
- Techniques:
  - Wet chemistry methods like titration.
  - Ion chromatography for sulfate and nitrate ions.
- ***(b) Gravimetric Analysis:***
- Measures the mass of particulates collected on filters.
- Procedure:
  - Weigh filters before and after sampling using a microbalance.
  - The difference in mass represents the particulate concentration.
- ***(c) Volumetric Analysis:***
- Used to determine gas concentrations by measuring the volume of the sample reacted or produced.
- Applications:
  - Quantifying gases like CO_2 or SO_2.

- ***(d) Colorimetric Analysis:***
- Measures changes in color intensity due to a chemical reaction.
- Applications:
  - Determining nitrogen dioxide (NO_2) using Griess-Saltzman reagent.
- ***(e) Turbimetric Analysis:***
- Measures the scattering of light by suspended particles in a liquid.
- Applications:
  - Determining particulate concentrations in aqueous samples.
- ***(f) Instrumental Chromatographic Methods:***
- Separate and quantify components of a particulate sample.
- Techniques:
  - Gas Chromatography (GC) for volatile organic compounds.
  - High-Performance Liquid Chromatography (HPLC) for polar compounds.

- **3. Spectrometric Methods**
- ***(a) Emission and Absorption Spectrometry:***
- Analyze the elemental composition of particulates.
- Flame Emission Spectroscopy (FES): Measures light emitted by elements in a flame.
- Atomic Absorption Spectroscopy (AAS): Quantifies metals like lead and cadmium.
- ***(b) X-Ray Diffraction (XRD):***
- Used for identifying crystalline structures in particulates.
- Applications:
  - Detecting minerals like silica or asbestos in air samples.
- ***(c) Mass Spectrometry (MS):***
- Measures the mass-to-charge ratio of particles to determine their molecular composition.
- Applications:
  - Identifying organic compounds, metals, and isotopes.

- ***(d) Polarography:***
- Measures current variations due to the reduction of ions.
- Applications:
  - Detecting trace metals like mercury or arsenic.
- ***(e) Radioactivity Analysis:***
- Measures radioactive particulates using Geiger counters or scintillation detectors.
- Applications:
  - Monitoring radionuclides like radon and thorium in air.
- ***(f) Microscopy:***
- Visual analysis of particulate morphology and size distribution.
- Types:
  - Scanning Electron Microscopy (SEM): High-resolution imaging.
  - Transmission Electron Microscopy (TEM): Identifying ultrafine particles.

- **4. Biological Methods**
- ***(a) Effects on Plants:***
- Bioindicators: Certain plants are sensitive to pollutants like ozone and sulfur dioxide.
- Visible Symptoms: Necrosis, chlorosis, and stunted growth.
- ***(b) Effects on Animals:***
- Toxicological Studies: Assess the effects of particulates on respiratory and cardiovascular systems in animal models.
- ***(c) Sensory Tests:***
- Odor Detection: Human sensory panels evaluate odors caused by particulates or associated gases.
- Applications:
  - Identifying nuisance levels of pollutants.

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Thank you