UNIT 3 AIR POLLUTION

What is Air Sampling?

Air sampling is the process of collecting and measuring pollutants or particles in the air to analyze their quantity, type, and potential impact on health and the environment.

Types of Contaminant

→ According to their physical properties

1) Particulates
2) Vapours
3) Gases

→ Particulates can be further subdivided into 5 types

1) Aerosols
2) Dusts
3) Fumes
4) Smokes
5) mists

Air sampling based on the Particulate:

Air Sampling based on Particulate pollutant

→ The following are the Air sampling techniques for particulate pollutants

1) Sedimentation
2) Filtration
3) Impengement
4) Precipitation → a) Thermal precipitation
   b) Electrostatic precipitation

Filter-Based Sampling

- **Principle**: Air is drawn through a filter, which traps particulates for gravimetric or chemical analysis.
- **Equipment**:
  - Glass fiber or Teflon filters (for gravimetric analysis).
  - Quartz filters (for carbon analysis).
- **Application**:
  - Mass concentration measurement.
  - Chemical characterization of particulates.

Electrostatic Precipitation

- **Principle**: Particles are charged using an electric field and collected on an oppositely charged plate.
- **Equipment**: Electrostatic Precipitators.
- **Application**:
  - Collection of ultrafine particles.
  - High-efficiency particulate sampling.

Cyclone Sampling

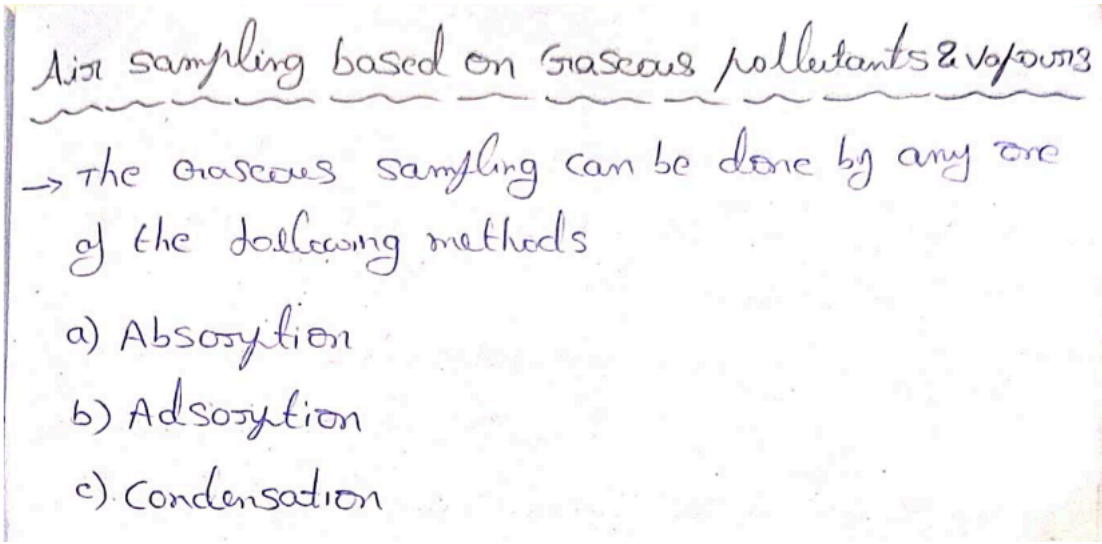
- **Principle**: Uses centrifugal force to separate particulates by size. Particles are spun out of the air stream and collected.
- **Equipment**: Cyclone Separators.
- **Application**:

- Pre-separation of coarse particles before further analysis.
- Workplace safety monitoring.

Gravimetric Sampling

- **Principle**: Particulates are collected on a filter, and their mass is measured by determining the weight difference before and after sampling.
- **Equipment**:
  - High-Volume Samplers (for PM10).
  - Low-Volume Samplers (for PM2.5).
- **Application**:
  - Compliance with air quality standards.
  - Long-term air quality monitoring.

Air Sampling methods based on the Gaseous



Air sampling based on Gaseous pollutants & vapours

→ The Gaseous sampling can be done by any one of the following methods

a) Absorption

b) Adsorption

c) Condensation

1. Absorption Methods (Using Liquids)

- **How It Works**:
  - The air containing gases is bubbled through a liquid (like a chemical solution).
  - The gas dissolves in the liquid if it is chemically compatible (e.g., acidic gases dissolve in alkaline solutions, and basic gases dissolve in acidic solutions).
- **Equipment Used**:
  - Bottles or devices called *impingers* that hold the liquid and allow air to pass through.
- **Examples**:
  - **SO_2 (Sulfur Dioxide)**: Captured in a solution like NaOH (sodium hydroxide).

    - **NH_3 (Ammonia)**: Captured in an acidic liquid and then measured for concentration using instruments like spectrophotometers (devices that measure light absorption).
- **Why It's Good**:
    - Very effective for gases that easily dissolve in liquids.
    - You can test for multiple gases at the same time using different liquid solutions.

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2. Adsorption Methods (Using Solids)

- **How It Works**:
    - The air is passed over a solid material (like activated charcoal or silica gel) that captures the gas molecules by holding them on its surface (like a sponge absorbing water, but for gases).
    - Later, the gases are released (by heating or another method) for analysis.
- **Equipment Used**:
    - **Sorbent Tubes**: Small tubes filled with solid materials like charcoal or Tenax.
    - **Thermal Desorption Units**: Devices that heat the solid to release the captured gas for measurement.
- **Examples**:
    - **VOCs (Volatile Organic Compounds)**: Chemicals like benzene and toluene (found in fumes or emissions) are trapped in the sorbent material and then analyzed.
- **Why It's Good**:
    - Very efficient for trapping gases that don't dissolve well in liquids.
    - Works well for both field (outdoor) and lab use.

Key Difference:

- **Absorption**: Gases dissolve into a liquid.
- **Adsorption**: Gases stick to the surface of a solid.

Both methods are commonly used to capture and analyze different types of air pollutants effectively.

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Sampling particulate and gaseous pollutants involves collecting and analyzing air pollutants to understand their concentrations and potential health or environmental effects. This process is applied in **stack emissions**, **ambient air**, and **indoor air pollution** studies. Here's an overview of each:

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1. Stack Sampling

Stack sampling involves monitoring emissions released from industrial stacks (chimneys or vents). This method measures pollutants directly at the source.

Steps for Stack Sampling

1. **Selection of Sampling Location**: Ensure a representative point in the stack is chosen.
2. **Isokinetic Sampling**: Collect samples at the same velocity as the gas in the stack to avoid particle loss.
3. **Equipment Used**:
   - **Probe**: For extracting gas and particulates.
   - **Filter Holder**: To capture particulate matter.
   - **Gas Analyzer**: For gaseous pollutants (SO_2, NO_x, CO, etc.).
   - **Velocity Meter**: Measures the stack gas velocity.
4. **Methods**:
   - Gravimetric methods for particulates (weighing filters before and after sampling).
   - Absorption or chemical methods for gases (e.g., SO_2 using impingers).
5. **Analysis**: Collected samples are analyzed in a lab for pollutant concentrations.

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2. Ambient Air Sampling

Ambient air sampling measures pollutants present in the open environment to assess air quality and compliance with standards (e.g., WHO or local guidelines).

Steps for Ambient Air Sampling

1. **Selection of Sampling Sites**: Locations with varying pollution levels (e.g., urban, rural, industrial zones).
2. **Sampling Equipment**:
   - **High-Volume Air Samplers**: Collect large volumes of air to capture particulate matter (PM_{10}, $PM_{2.5}$).
   - **Low-Volume Samplers**: For precise measurement of specific pollutants.
   - **Diffusion Tubes**: For passive sampling of gases like NO_2 and O_3.
3. **Types of Sampling**:
   - **Continuous Monitoring**: Using real-time analyzers.
   - **Grab Sampling**: Collects air for short-term analysis.
   - **Integrated Sampling**: Over a longer period (e.g., 24 hours) to understand average pollutant levels.
4. **Analysis**: Collected filters or tubes are analyzed in the lab for particulate mass and gaseous pollutants.

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3. Indoor Air Sampling

Indoor air sampling focuses on pollutants in enclosed spaces (homes, offices, factories) where sources like combustion, building materials, and human activities may contribute.

Steps for Indoor Air Sampling

1. **Selection of Sampling Locations**: Identify representative points (kitchen, living rooms, offices).
2. **Sampling Equipment**:
   - **Passive Samplers**: For long-term monitoring of gases (e.g., radon, VOCs).
   - **Active Samplers**: Require pumps to collect air samples.
   - **Real-Time Monitors**: Measure pollutants like CO_2, VOCs, and particulate matter instantly.
3. **Key Pollutants Monitored**:
   - **Particulates**: PM_{10}, $PM_{2.5}$.
   - **Gases**: CO_2, CO, VOCs, radon.
   - **Biological Contaminants**: Mold spores, bacteria.
4. **Analysis**: Includes lab analysis or data download from real-time monitors.

Challenges in Sampling

1. **Environmental Conditions**: Temperature, humidity, and wind affect measurements.
2. **Accuracy**: Ensuring representative samples, especially for particulate matter.
3. **Calibration**: Maintaining calibrated instruments for reliable data.

Importance of Sampling

- **Health Risk Assessment**: Identify pollutant levels impacting human health.
- **Regulatory Compliance**: Meet environmental laws and standards.
- **Source Identification**: Determine pollutant origins (industrial, vehicular, domestic).

(or)

Let me simplify the explanation for you! Sampling particulate and gaseous pollutants means collecting air samples to check for harmful particles or gases in the environment. The purpose is to measure how much pollution is present and whether it's safe for humans and the environment. This can be done in **three main areas**: **stack emissions**, **ambient air**, and **indoor air**.

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1. Stack Sampling

This is for checking pollution coming directly from factories or industrial chimneys (called stacks).

How it's Done:

- **Find a good spot** in the chimney for sampling.
- **Use isokinetic sampling**, meaning collect samples at the same speed as the gas flows to avoid errors.

Tools Used:

- A **probe**: A tube to collect gas and particles.
- A **filter holder**: To trap tiny solid particles (dust).
- A **gas analyzer**: To measure gases like sulfur dioxide (SO_2), nitrogen oxides (NO_x), or carbon monoxide (CO).

What's Measured:

- Particles are weighed to see how much is present.
- Gases are analyzed using chemicals or instruments.

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2. Ambient Air Sampling

This is for checking pollution in outdoor air, like the air in cities, villages, or near factories.

How it's Done:

- **Choose locations** that represent different environments (busy streets, parks, industrial zones).
- Collect air using special tools for short-term (few minutes) or long-term (24 hours) measurements.

Tools Used:

- **High-Volume Samplers**: To collect a lot of air and check for particles like $PM_{2.5}$ and PM_{10} (tiny dust particles).
- **Diffusion Tubes**: For collecting gases like nitrogen dioxide (NO_2) or ozone (O_3) without any machine.

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3. Indoor Air Sampling

This is for checking pollution inside buildings like homes, offices, or factories.

How it's Done:

- **Select locations** where pollution is suspected (e.g., kitchen or office).
- Collect air samples using small devices.

Tools Used:

- **Passive samplers**: Work on their own and collect air over time.
- **Active samplers**: Use a pump to pull air into the device.
- **Real-time monitors**: Give immediate results for gases like carbon dioxide (CO_2) or volatile organic compounds (VOCs).

What's Measured:

- Dust particles ($PM_{2.5}$, PM_{10}).
- Gases like CO_2, CO, and radon.
- Mold or bacteria.

Challenges in Sampling

1. **Weather**: Temperature or wind can affect results.
2. **Accuracy**: It's tricky to collect air that represents the real pollution level.
3. **Calibration**: Instruments need to be properly adjusted for correct readings.

Why Sampling Matters

1. **Protects health**: Helps identify harmful pollution levels that can cause diseases.
2. **Follows laws**: Ensures industries follow pollution control rules.
3. **Finds sources**: Identifies where pollution is coming from (factories, vehicles, etc.).

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1. Particulate Matter ($PM_{2.5}$ and PM_{10}) Monitoring

a. Gravimetric Method

- **Principle**: The weight of particulate matter collected on a filter is measured. The difference in the filter's weight before and after sampling gives the mass of particles collected.
- **Process**:
  1. Air is drawn through a pre-weighed filter using a vacuum pump.
  2. Particulates in the air are trapped on the filter.
  3. After sampling, the filter is conditioned (under controlled temperature and humidity) and weighed again.
  4. The mass of particulates is divided by the air volume to calculate concentration (μg/m³).
- **Advantages**: High accuracy, standard method for regulatory purposes.
- **Limitations**: Time-consuming and not suitable for real-time data.

b. Real-Time Monitors

- **Principle**: Optical or laser-based techniques measure the scattering of light caused by particulates.
- **Process**:
    1. A beam of light (laser or infrared) is passed through a chamber where air flows.
    2. Particles scatter the light, and the amount of scattering is proportional to the concentration of particulates.
    3. Devices like beta attenuation monitors also use beta radiation to measure particulate density by detecting the attenuation of radiation passing through the particles.
- **Advantages**: Continuous, real-time data.
- **Limitations**: Can be affected by humidity and particle composition.

c. Portable Air Quality Monitors

- **Principle**: Miniaturized versions of optical methods or low-cost sensors detect particulate matter.
- **Process**: Similar to real-time monitors but designed for short-term, on-site measurements.

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2. Sulfur Oxides (SO_x) Monitoring

a. UV Fluorescence Method

- **Principle**: SO_2 absorbs ultraviolet light and re-emits it as fluorescence. The intensity of fluorescence is directly proportional to the SO_2 concentration.
- **Process**:
    1. Air containing SO_2 is drawn into the instrument.
    2. SO_2 molecules are exposed to UV light, causing them to fluoresce.
    3. A detector measures the intensity of fluorescence and calculates SO_2 concentration.
- **Advantages**: Highly sensitive and precise.
- **Limitations**: Requires calibration and maintenance.

b. Wet Chemistry (Pararosaniline Method)

- **Principle**: SO_2 reacts with pararosaniline and formaldehyde to form a colored compound, whose intensity is measured spectrophotometrically.
- **Process**:
    1. Air is bubbled through an absorbing solution containing pararosaniline.
    2. The chemical reaction produces a colored solution.
    3. The color intensity is measured using a spectrophotometer to determine SO_2 concentration.
- **Advantages**: Simple and low-cost.
- **Limitations**: Time-consuming and not suitable for real-time monitoring.

3. Nitrogen Oxides (NO_x) Monitoring

a. Chemiluminescence Method

- **Principle**: NO reacts with ozone (O_3) to produce nitrogen dioxide (NO_2) and light (chemiluminescence). The intensity of the light indicates the NO concentration.
- **Process**:
    1. Air is sampled, and NO is separated.
    2. NO reacts with O_3 in a reaction chamber.
    3. A photodetector measures the light emitted during the reaction.
    4. Total NO_x concentration is calculated after converting NO_2 to NO thermally.
- **Advantages**: High precision and real-time capability.
- **Limitations**: Requires regular calibration and maintenance.

b. Passive Samplers

- **Principle**: NO_2 diffuses onto an absorbing medium (e.g., impregnated filters), where it reacts chemically.
- **Process**:
    1. The sampler is exposed to air for a set duration.
    2. NO_2 reacts with the absorbent and forms a stable compound.
    3. The collected sample is analyzed in a laboratory to determine NO_2 concentration.
- **Advantages**: Low-cost, long-term monitoring.
- **Limitations**: Limited to average concentrations over time.

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4. Carbon Monoxide (CO) Monitoring

a. Non-Dispersive Infrared (NDIR) Method

- **Principle**: CO absorbs infrared radiation at specific wavelengths. The amount of absorbed IR is proportional to the CO concentration.
- **Process**:
    1. Infrared light is passed through a sample of air.
    2. CO molecules absorb some of the light.
    3. A detector measures the intensity of transmitted IR, and the concentration of CO is calculated.
- **Advantages**: Accurate and suitable for continuous monitoring.
- **Limitations**: Requires clean optics to avoid interference.

b. Electrochemical Sensors

- **Principle**: CO reacts at an electrode surface, generating an electric current proportional to its concentration.
- **Process**:

1. Air passes over a sensing electrode.
2. CO reacts with the electrode, causing a chemical reaction.
3. The resulting current is measured to determine CO levels.

- **Advantages**: Portable and cost-effective.
- **Limitations**: Limited lifespan and calibration requirements.

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5. Ammonia (NH_3) Monitoring

a. Chemical Absorption Method

- **Principle**: NH_3 reacts with an acidic solution to form a compound that can be quantified using spectrophotometry.
- **Process**:
  1. Air is bubbled through an acidic absorbing solution.
  2. NH_3 reacts to form ammonium ions.
  3. The solution is analyzed using a spectrophotometer to determine NH_3 concentration.
- **Advantages**: Reliable for laboratory analysis.
- **Limitations**: Time-intensive.

b. Tunable Diode Laser Absorption Spectroscopy (TDLAS)

- **Principle**: A laser beam tuned to NH_3's absorption wavelength measures the attenuation caused by NH_3 molecules.
- **Process**:
  1. A laser passes through a sample containing NH_3.
  2. NH_3 absorbs specific wavelengths of the laser light.
  3. A detector measures the reduction in light intensity to determine NH_3 levels.
- **Advantages**: High precision and real-time monitoring.
- **Limitations**: Expensive and complex.

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6. Analysis Methods

a. Gravimetric Analysis

- Weigh filters before and after sampling to determine particulate concentrations.
- Accurate but time-intensive.

b. Ion Chromatography

- Separates and quantifies ions like sulfate (SO_4^{2-}) and nitrate (NO_3^-) from liquid samples.

c. Gas Chromatography (GC)

- Separates gases like CO and VOCs for precise quantification.

d. Mass Spectrometry (MS)

- Detects and quantifies pollutants at very low concentrations with high accuracy.

This detailed explanation outlines the working principles, processes, and strengths of each monitoring technique, ensuring clarity and comprehensive understanding. Let me know if you'd like further details!

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Gauss Plume Dispersion

- A model used to predict how air pollutants spread from a source (like a smokestack or factory) into the atmosphere.
- It assumes the pollutants disperse in a bell-shaped pattern (like a Gaussian curve) as they travel downwind from the source.

The **Gaussian Plume Dispersion Model** is a widely used method in environmental engineering to predict the dispersion of air pollutants emitted from a point source, such as a smokestack or exhaust pipe. It is based on the assumption that the plume of pollution behaves in a Gaussian distribution (bell-shaped curve) in the horizontal and vertical directions as it moves downwind from the source.

The model is used to estimate the concentration of pollutants at various locations downwind of the emission source, accounting for factors like wind speed, atmospheric stability, and terrain. It assumes that the dispersion of pollutants is influenced by turbulence in the air, which causes the pollutants to spread both horizontally and vertically.

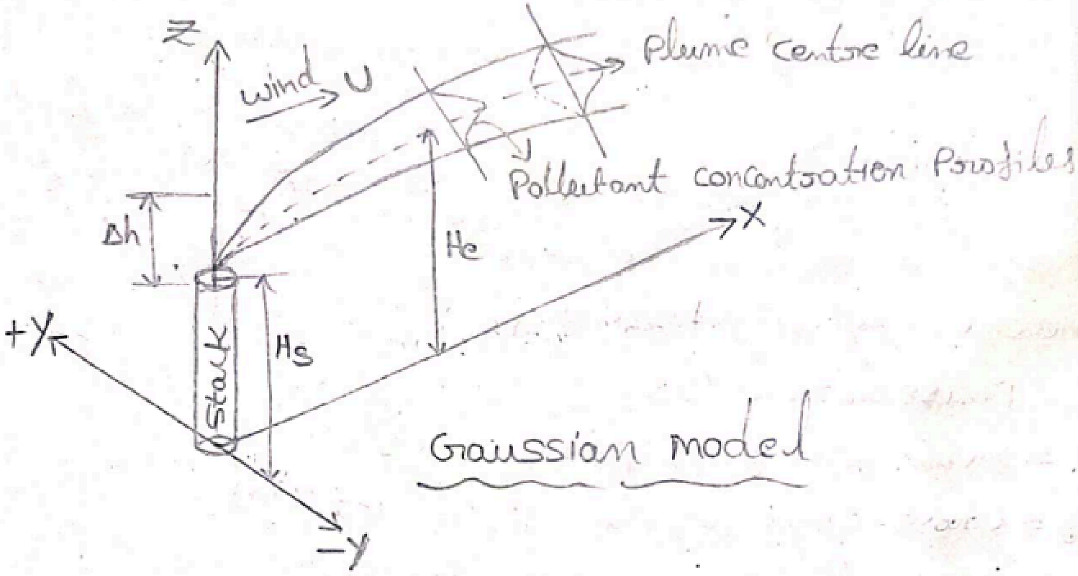
. It is based on assumption like

i) Stack gas transported downstream

ii) Dispersion in vertical direction is governed by atmospheric stability

iii) Dispersion in horizontal plane is governed by molecular & eddy diffusion.

→ The plume spread & shape vary in response to meteorological conditions.



where H_s = Actual stack height

H_e = Effective stack height = $H_s + \Delta h$

Δh = Plume rise

Key Components:

1. **Source strength**: The rate at which pollutants are emitted from the source.
2. **Meteorological conditions**: Factors like wind speed, wind direction, and atmospheric stability (e.g., stability classes such as A to F, from very unstable to very stable conditions).
3. **Dispersion parameters**: The horizontal and vertical dispersion coefficients, which depend on factors such as wind speed, turbulence, and distance from the source.
4. **Distance**: The downwind distance from the pollutant source.

→ The plume in general tries to flow in upward direction due to exit velocity & buoyancy effects

→ But due to the prevailing wind, the plume turns into downward direction

→ The plume while travelling in downward direction diffuses & assumed to take the shape of the concentration profile given by Gaussian model technique as shown in above fig.

→ The concentration decreases in the downward direction (being maximum at centre-line)

→ The pollution concentration at any point is given by
$C(x,y,z) \propto Q \frac{G}{U}$; G = Normalized gaussian curve in yz
U = wind speed, Q - Emission flow rate

The **Gaussian Plume Dispersion Model** uses mathematical equations to estimate the concentration of pollutants at different points downwind from a source. The general form of the equation for a continuous emission from a point source is:

Gaussian Plume Equation

$$C(x,y,z) = \frac{Q}{2\pi\sigma_y\sigma_z u} \exp\left(-\frac{y^2}{2\sigma_y^2}\right) \left[\exp\left(-\frac{(z-H)^2}{2\sigma_z^2}\right) + \exp\left(-\frac{(z+H)^2}{2\sigma_z^2}\right)\right]$$

Where:

- $C(x,y,z)$ = Concentration of the pollutant at the point (x,y,z) in space.
- Q = Emission rate of the pollutant (mass per unit time, e.g., kg/s).
- x = Downwind distance from the source (horizontal direction).
- y = Lateral distance from the centerline of the plume (perpendicular to the wind direction).
- z = Height above the ground at which the concentration is being calculated.
- H = Height of the emission source (e.g., smokestack).
- σ_y = Standard deviation of the plume in the lateral direction (horizontal spread).
- σ_z = Standard deviation of the plume in the vertical direction (vertical spread).
- u = Wind speed at the ground level.
- $\exp$ = Exponential function.

Key Uses:

1. **Predicting Air Quality**: Helps estimate the concentration of pollutants at different distances from the source.
2. **Regulatory Compliance**: Ensures that factories and power plants don't release harmful levels of pollutants into the air.
3. **Site Planning**: Used to design industrial sites by determining where to place smokestacks or exhausts to minimize pollution impact.
4. **Environmental Risk**: Assesses how air pollution might affect the environment and human health in nearby areas.
5. **Emergency Response**: Helps predict how pollutants will spread if there's an accidental chemical spill or leak.
6. **Pollution Control**: Aids in designing systems (like filters or scrubbers) to reduce harmful emissions.
7. **Urban Pollution Management**: Used to study pollution levels in cities and identify pollution hotspots for better management.

Limitations:

- Works best in simple, flat areas (not complex terrains).
- Assumes pollution spreads steadily (which may not always be true).

In simple terms, the Gaussian model is a tool to understand and manage how air pollution moves from a source to the surrounding environment.