Types of pollutant sampling and measurement:

Air quality monitoring:

Sampling and measurement of air pollutants generally known, as air quality monitoring.
It is an integral component of any air pollution control programme.

Monitoring is important:

1. Air quality can be evaluated
2. Information is helpful in implementing control measures for reducing pollutant concentration to acceptable levels
3. Assessing the effect of air pollution control strategies.

Classification of sampling methods:

1. Sampling of impurities of every nature (Ranging from particulate matter to gases)
2. Sampling under various environmental conditions (ranging from samples taken from chimneys to samples taken in the open air)
3. Sampling methods varying according to the time factor (Ranging from intermittent to continuous sampling)

Air Quality measurement is undertaken in two situations:

1. Ambient air quality measurement
2. Stack monitoring

Ambient air quality measurement: Where the pollutant levels in the ambient atmosphere are measured.

Stack sampling: It deals with the pollutants emitted from a source such as smoke stack and is known as stack sampling.

It provides information on the nature and quantities of various pollutants that are emitted into the atmosphere.
**Difficulties encountered in sampling:**

1. Collecting samples of true representative character

2. Errors arising from methods used for the collection and separation of the various components of pollution.

3. Difficulty in preventing any change in the concentration of particulate matter in suspension, as a result of sampling operation.

**1. Preliminary considerations and stages of sampling:**

   Following principles should be followed to ensure correct sampling

**2. Statistical studies**

   Important to establish the basic data e.g. size and frequency of sampling
   It use the basic principles of the probability

**3. Size of samples**

   The sample should be large enough to make analysis possible.

**4. Change in the sample during and after sampling**

**5. Continuous and intermittent sampling**

   An automatic continuous recording apparatus is preferable.

**6. Sampling of volatile constituents**

   Carry out sampling with large volumes of air (To avoid error)

**7. Sampling of particulates**

   **Errors** may be introduced due to agglomeration or breaking up of particulate matter.
In order to eliminate the sources of error,

- Sampling should be carried out under conditions that are as isokinetics as possible
- A gas stream should be sampled as far as possible in the same direction and at the same speed itself but never counter-current
- The collection surface should be as close as possible to the source of the gas stream. To avoid reducing the efficiency of sampling, deposits and condensation should not be allowed to form on the walls of sampling vessels.

8. Sampling of waste gas

Difficulties are encountered due to high temperature, lack of uniformity in the composition of gas flow and difference in speed due to disturbances.

Hence to avoid error, the gas stream should be sampled at several points and maximum number of samples should be taken to get the average value.

9. Sampling in the open air

Difficulties arise due to,

- High dilution of the pollutants dispersed in air
- Consequent need to collect large number of samples
- Difficulty of sampling under isokinetic conditions.

To minimize the error of sampling continuous recording instruments should be used and samples should be collected at various places. Also meteorological data like wind speed and direction, should e collected to know their effects on dilution or concentration of pollutant in the air.
Basic consideration of air sampling

1. The sample collected must be representative in terms of time and location
2. The sample volume should be large enough to permit accurate analysis
3. The sampling rate must be such as to provide maximum efficiency of collection
4. The duration of sampling and frequency of sampling should reflect accurately the occurrence of fluctuations in pollution level
5. The contaminants must not be modified or altered in the process of collection

Instruments for sampling waste gases and for atmospheric sampling

1. Devices for general use
2. Devices for sampling gases and vapors

1. Devices for general use

Meters:

They are used to determine accurately the volume of the gas collected. They are fitted with manometers and thermometers to indicate the pressure and temperature of the gas stream sampled.

Probes:

They are tubes suitable for penetrating into the gas stream and should be constructed of material, which are non-corrosive and which can withstand special temperature conditions.

They should be constructed of materials (S. S, Glass or Quartz) that do not react with the substances to be sampled.

A probe should have suitable length and diameter.

To ensure isokinetic sampling condition the opening of the probe should face the gas stream to be sampled.
Suction Devices:

Any suction device that has the required volumetric capacity can be used.
Vacuum pumps driven by electric motors are very commonly used.

2. Devices for sampling gases and vapors

Absorbers:

Effluent gases are passed through absorber (scrubbers) which contain liquid absorbents that remove one or more of the pollutants in the gas stream.

The efficiency of this process depends on
1. Amount of surface contact between gas and liquid
2. Contact time
3. Concentration of absorbing medium
4. Speed of reaction between the absorbent and gas

Absorbent are being used to remove sulphur dioxide, hydrogen sulphide, sulphur trioxide and fluorides and oxides of nitrogen

Equipments using the principle of absorption for the removal of gaseous pollutants includes (1) Packed tower (2) Plate tower (3) bubble cap plate tower (4) Spray tower (5) Liquid jet scrubber absorber.

A gas can be sampled by means of a suitable absorption reagent. For this purpose, U-shaped absorbers are used.

This absorber is filled with a certain amount of reagent and fitted with a porous glass partition. So that the air or gas led into them passes through the reagent solution in the form of fine bubbles thus ensuring intimate contact. Sampling is carried out at an average rate of about 100 – 150 liters per hour of gas stream.

Oxides of sulphur, Oxides of nitrogen, Ammonia, Hydrogen sulphide, Hydrochloric acid, Hydrofluoric acid, Hydrocynic acid, ozone, H/C, organic solvent are measured (0.1 ppm by volume)
Sampling train

(i) Adsorbers:

Adsorption is brought about by aspiring the air or gas to be sampled through adsorption column containing silica gel, activated charcoal or another suitable agents.

After adsorption, the different pollutants can be extracted from the column in various ways. e.g. by rising the temperature

Difficulties: Selecting a suitable adsorbing medium

Application: used for ozone and light H/C

(ii) Condensers:

The gas stream sampled is cooled in suitable containers, thus bringing about the condensation of the Volatile substances.

Condensation trap can be arranged either series or parallel at decreasing temperature.

Using various coolants e.g. ice, liquid air or liquid nitrogen can separate the components separated by fractional condensation.

Used for the sampling of odoriferous substances.
(iii) Collector under reduced pressure:

For some substances like nitric acid and aldehydes having high molecular weight, absorption in aqueous solution is sometimes incomplete.

In such cases, it is to use bottles of known volume of collecting under a pressure reduced to 200 mm Hg or even less.

The absorbent solution chosen is first introduced into the bottle and the pressure is thus reduced. Then the sample is admitted until the internal and external pressures are equal and the container is shaken continuously so as to ensure maximum absorption.

Use for sampling the oxides on N2

(iv) Plastics containers:

Special polyethylene bags are used for collecting and transporting large volume of air.

Advantages:

They can be used for successive analysis of small fractions of sample taken.
Polyethylene is inert with respect to many substances including SO2, and formaldehyde

Plastics bags are not suitable for collecting and storing aerosol suspensions because of the possible generation of electrostatic charges, as a result of which the aerosol tend to move towards the walls and condense on them.

Used for grab sampling and sample storage before analysis

(v) Samples for Mass Spectrometric analysis

Sampling for mass spectrometric analysis can be carried out by compressing the gas sample in a pressure flask so as to concentrate a large quantity of gas in a small volume or by fling evacuated containers.
Duration of Sampling Period:

Two types of sampling are used (1) Short period or Spot sampling and (2) Continuous sampling

It is used to evaluate peak and average concentration over definite time intervals.

Spot sampling:

Samples are collected over periods varying from less than 30 minutes to several hours for specific proposes.

The choice of sampling period depends upon

- Nature of the component under study
- Its stability to oxidation, light or other factors such as sensitivity, accuracy and precision of the analytical method to be used.

Short sampling is useful for the random checking of pollution at many points.

Such samples have limited value because pollution levels fluctuate widely depending on meteorological conditions, topographical features and various factors associated with sources of pollution (e.g. Mass rates of emission of pollutants form smoke stacks, the temperature, velocity and density of stack gases the height of smoke stacks, the distribution of sources and downwind distance form the sources to the points where the measurement are made).

Continuous sampling:

Techniques are useful in systematic studies of the nature and extent of air pollution if the data are to be value for epidemiological surveys, for evaluating the potential hazards to man, animal or vegetation and for control programmes.

It can be carried out by the subsequent analysis of pollutant by appropriate analytical techniques.
Location of sampling sites:

Sampling sites must be carefully selected so as to be representatives of the area under study.

A representative number of sampling stations for a given area may be established by means of a preliminary survey whose objectives should be:

1. To gather information on the nature and magnitude of the emission from principal sources of pollution.
2. To review the available climatologically and meteorological data.
3. To gather data on the concentration of pollutants in areas of severe and slight air pollution.

Collection of Gaseous air Pollutants:

1. Grab sampling
2. Absorption in liquid
3. Adsorption on solids
4. Freeze-out Sampling

1. Grab sampling

In grab sampling the sample is collected by filling an evacuated flask or an inflatable bag. Plastic bags are widely used.

Bag sampling: Disadvantages: Losses caused by moisture condensation or diffusion through the walls of the bag. The losses can be minimized by performing the analysis immediately following collection. Grab sampling may be taken using rigid wall containers made from glass or stainless steel.
2. **Absorption in liquid**

Absorption separates the desire pollutant from air either through direct solubility in the absorbing medium or by chemical reaction.

1. Fitted glass absorber
2. Impingers

1. **Fitted glass absorber**
The gas stream is broken up into extremely small bubbles, thus promoting an intimate contact between the gas and the liquid. Frits designated coarse (50micron m pore size) are used for air sampling. The glass frit can become blocked and is difficult to clean after use. So pre filter the air prior to sampling.

2. **Impingers**
In the Impingers the gas stream is impinged at high velocity onto a flat surface thus providing good contact between the gas and liquid. The flat surface can be the bottom of the collector or a specially designed pate. Two types of Impingers: (1) Wet Impingers (2) Dry Impingers

**Wet Impingers**
Collect a particle by causing them to impinge a surface submerged in a liquid.

**Dry Impingers:**
Referred to as impactors collect particles by impaction on a dry surface.

In both the apparatus, collection results as result of inertial force as the particles tend to resist a change in the direction when the air stream is deflected by a surface or other obstacle. The efficient is very high whose diameter is 1 μ or grater.

There are two types if Impingers (wet collector)

(i) Greenberg- Smith
(ii) Midget type

Devices can handled sample flow rate of about 30 and 3 liter per minute respectively Easy to clean and maintain.
Standard large impingers

Midget fitted impingers  Standard midget impingers

Dry cascade impactors are also used. They are useful for simultaneous collecting and size differentiating of an aerosol.
**Adsorption on solids:**

This method is based on the tendency of gases to be adsorbed on the surface of solid materials.

The sample air is passed through a packed column containing a finely divided solid adsorbent on whose surface the pollutants are retained and concentrated.

**Solid adsorbent:** Granular porous solids: Activated Charcoal, Silica gel

After adsorption, the sample gases are desorbed for analysis. This may be accomplished by heating the adsorbent to volatilize the trapped materials or by washing it with a liquid solvent.

Most organic vapors are analyzed by gas chromatographic techniques that directly use the adsorption of the gases.

**Disadvantages:** Desorption of gases are complicated

**Freeze out Sampling:**

In freeze out sampling a series of cold traps, which are maintained at progressively lower temperature, are used to draw the air sample, whereby the pollutants are condensed.

The traps are brought to the laboratory, the samples are removed and analyzed by means of gas chromatographic, infrared or ultraviolet, spectrophotometer, and mass spectrometry or by wet chemical means.

**Disadvantages:** Plugging of the system because of Ice formation

### Coolants used for freeze-out traps

<table>
<thead>
<tr>
<th>Coolant</th>
<th>Temp. Attained (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice-water</td>
<td>0</td>
</tr>
<tr>
<td>Ice-salt</td>
<td>-21</td>
</tr>
<tr>
<td>Dry ice and acetone</td>
<td>-79</td>
</tr>
<tr>
<td>Liquid air</td>
<td>-147</td>
</tr>
<tr>
<td>Liquid oxygen</td>
<td>-183</td>
</tr>
<tr>
<td>Liquid nitrogen</td>
<td>-196</td>
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</tbody>
</table>
Collection of particulate pollutants:

Particulate pollutants

Settle due to the **force of gravity**
( Particle size greater than 10 µm)
**Sedimentation**

Those that remain **suspended as aerosols**
( Smaller size)
**Filtration**
**Impingement**
**Electrostatic**
**Thermal Precipitation**

**Sedimentation (Dust fall Jar):**

Suitable for larger particles having a size more than 10 µ.
The jar method for dust fall is based on sedimentation.
Greasy slides can also be used for trapping the sedimented particles.

**Dust fall jar with guard frame and stand**

**General considerations in site selections are:**

1. The site should be **free from overhead obstructions** and **away from inference** by local sources such as an **incinerator or chimney**.
2. The **mouth** of the dust fall collector should be **no less than 2.5 m and no more than 16 m above ground level**, with a **standard height of 6 m as recommended elevation**
3. When sampling in urban areas, the dust fall collector should be set no less than 10 stack lengths from an operating smoke stack and no closer to vertical wall than the distance that provides an 30° angle from the sampler to the top of the wall or roof.
Advantages:

- Ease of procurement of 1-5 gram of weightable sample, on which a number of chemical and physical analyses can be performed.
- The method is simple and inexpensive and required no electrical power or moving parts.

It facilitates:

(a) Collection of dust that is representative of a given industry or community.
(b) Detection of process changes of a given industry
(c) Survey of a community to determine areas of high versus low levels of dust pollution

Disadvantages:

- Lack of precision and inability to distinguish episode of peak dust fall due to integration of the total sample weight over the entire sampling period (up to 30 days)
- Particles collected are more less agglomerated and may not be representative of the original from and size of particulate matter suspended

Filtration:

The particulate matter form air can be sampled by passing the air through a filter whose pore size is small enough to retain the particles.

The selection of filter depends on (1) Objectives of sampling (2) size of the particles

Membrane filter: Study of the sizes and morphology
Glass fiber filter (nonhygroscopic): particles to be collected for measuring their weight.
High Volume Filtration (The Hi-vol sampler):
Impaction on solid surface:

When an air stream is deflected after sticking a surface, the particles are impacted due to inertial forces.

Collection efficiency is high for particle size 1 µ.

Sampler: Anderson impactor

Which has a series of plates with perforations having progressively decreasing pore sizes. Petri plates provided with some sticky substances are kept below these perforated plates.

The air passes through the larger pore size plate to smaller pore size plate. At each stage, as the air passes through the plates it strikes the sticky surface of the petri plates impacting the particles thereon.

The variation of the perforation sizes of h plates makes the velocity to vary, which the separation of particles of different sizes on different plates.

Impingement in liquid:

The particles are separated from the air by the force of inertia as the air is deflected after striking the liquid surface.

The bubbler or impingers used for collection of particles are the same those used for collection of gaseous pollutants.

Devices: (1) Green burg Smith standard
          (2) Midget Impingers

Limitations:
Not widely used for particulates because of low sampling rates
**Electrostatic Precipitation:**

During operation a negative charge is imparted to wire placed axially inside a cylinder that is positively charged.

When the particle laden air stream passes through the cylinder, the particles acquire a negative charge from a corona discharge occurring on the central wire.

The particles migrate towards the inner surface of the cylinder and are removed for subsequent chemical or microscopic analysis.

**Electrostatic Precipitator for collection of particulates**

**Thermal precipitation:**

Thermal precipitators operate on the principle that small particles, under the influence of a strong temperature gradient between two surfaces, have a tendency to move towards the lower temperature and get deposited on the colder of these two surfaces.

Theses temperature gradients are normally of the order of 3000 °C per centimeter.

To maintain such high gradients the gas velocity through the sampling device must be maintained low; this is usually between 10 and 200 ml per minute depending on the type of device.

**Efficiency**: High (Small particles) & 100 % or particles in the size range form 10µm down to 0.01 µm.

The particles are collected on a grid or a thin microscope cover glass for later analysis.
Centrifugal Methods:

Most centrifugal sampling devices are constructed on the principle of the cyclone.

The dust-laden gas moving at high velocity is directed tangentially into a cylindrical chamber, in which it forms a confined vortex.

The centrifugal force tends to drive the suspended particles to the wall of the cyclone body, from which they drop into a dust collection chamber.

An axial outlet is provided for the clean gas.

**Advantages:** procurement of a dry chemically pure sample

**Disadvantages:** particle size greater than 5 \( \mu \)

Solution Impingers:

This consists of a drawn out tube through which air containing particles flows into a solution, where the particles are trapped.

**Disadvantages:** unable to collect both particulate and vapor species.
For this purpose oxidizing solution is used.

Application is limited because the collection solution can be operated only at low flow rate (20 lit/min).

**Application:** high atmospheric particulates loading exits, Simultaneous collection of particles and gases are required or alternative equipments are not available.