Sampling

**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 plate.

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.
Sampling

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 of Impingers (wet collector)

- Greenberg- Smith
- Midget type

Devices can handled sample flow rate of about 30 and 3 liter per minute respectively

Easy to clean and maintain.
Sampling Impingers
Sampling

Midget fitted impingers

Standard midget impingers
Sampling

Adsorption:
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 analyses by gas chromatographic techniques that directly use the adsorption of the gases.

**Disadvantages:** Desorption of gases are complicated
Sampling

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 analyses 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
Sampling

Freeze out Sampling:

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>
</tr>
</tbody>
</table>
Sampling

Collection of particulate pollutants:

Particulate pollutants

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

**Sedimentation**

Those that remain **suspended as aerosols**
(Smaller size)

**Filtration**
**Impingement**
**Electrostatic**
**Thermal Precipitation**
## Classification of particulate matter

<table>
<thead>
<tr>
<th>EPA description</th>
<th>Particle size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Super coarse</td>
<td>$d_{pa} &gt; 10 \ \mu m$</td>
</tr>
<tr>
<td>Coarse</td>
<td>$2.5 \ \mu m &lt; d_{pa} \leq 10 \ \mu m$</td>
</tr>
<tr>
<td>Fine</td>
<td>$0.1 \ \mu m &lt; d_{pa} \leq 2.5 \ \mu m$</td>
</tr>
<tr>
<td>Ultrafine</td>
<td>$d_{pa} \leq 0.1 \ \mu m$</td>
</tr>
</tbody>
</table>
Classification of particulate matter

1. **Total suspended particulate matter (TSP)**
   Particles ranging in size from 0.1 \(\mu\text{m}\) to about 30 \(\mu\text{m}\)
   Particle sizes including: Fine, Coarse, Super coarse

2. **\(\text{PM}_{10}\)**
   Particle matter with a dia of 10 \(\mu\text{m}\) collected with 50 % efficiency

3. **\(\text{PM}_{2.5}\)**
   Particle matter with a dia of 2.5 \(\mu\text{m}\) collected with 50 % efficiency

4. **Particles less than 0.1 \(\mu\text{m}\)**
   0.01 \(\mu\text{m}\) to 0.1 \(\mu\text{m}\)

5. **Condensable particulate matter**
   Particulate matter that forms from condensing gases or vapors is referred to as Condensable particulate matter
Dust fall Jar

• Dust fall is the fraction of particulates which settles down quickly by virtue of their larger size.

• Simple techniques for collection of particulate matter.

• Suitable for larger particles having a size more than 10 µm.

• The jar method for dust fall is based on sedimentation.

• Dust Fall Jar is a device which enables the user to carry out dust fall monitoring in high dust areas such as open mining, excavations, constructions etc.

• It is a form of gravitational sampling system. It utilizes the principle that dust particles are usually coarse in size and that they settle slowly under the influence of gravity. It continues to be in use because of its inherent simplicity and low cost.
Dust fall Jar

- Simple open top cylindrical container having a flat bottom.
- \( d_{\text{cylinder}} \): more than 15 cm
- Height: 2 to 3 times of diameter
- Container made up of glass or plastic.
- It is kept little above the ground on a stand with a protection provided by a guard frame.
- Greasy slides can also be used for trapping the sedimented particles.
Dust fall Jar

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 30° angle from the sampler to the top of the wall or roof.
Dust fall Jar

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:

- Collection of dust that is representative of a given industry

- Detection of process changes of a given industry

- Survey of a community to determine areas of high versus low levels of dust pollution
Dust fall Jar

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
Dust fall Jar

Applications:

- Monitoring in urban areas
- Monitoring of open spaces like forests and national park air monitoring.
- Monitoring of ecologically sensitive monuments
- Short Time Surveys
- Mining Industry
- Waste Disposal and Burning sites
- Construction and Infrastructure Sites
- Data Collection and Reporting
Filtration

Â Settleable particles measured by dust fall collectors represent only a portion of air-borne dust.

Â Particulates having a diameter of less than 10 µ, according to stoke’s law tend to remain entrained in an air stream such particulates are referred to as suspended particulates.

Â Respirable particulates are harmful to man than the larger diameter Settleable particulates.

Filtration:

Â Particles are quantitatively removed from an air stream flowing through a dense material containing sub-micrometer pore size.

Â Any material that passes through such a filter is considered.
Filtration

There are several mechanisms that can act to cause particles to be separated from a gas stream.

Which specific mechanism or combination of mechanisms acts and which particular mechanism dominates is strongly dependent on particle size.

Particle collection is achieved by 5 processes

1. Direct interception (if its size is too great to permit it to pass through the filter pores)
2. Internal deposition (if its inertia is sufficiently great for it to impact on the solid structural material of the filter)
3. Diffusional deposition
4. Electrical attraction
5. Gravitational attraction

Each of these mechanisms applies one or more forces to a particle such as electrostatic force or inertial force to cause it to move to a collecting surface.
Filtration

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

**Selection of filter medium depends** on (1) Objectives of sampling (2) Types of particulates to be collected (3) Size of the particles (4) Chemical nature of filter

**Lab grade paper filter** is not use for sampling of ambient air as
- They are not satisfactory for recovery of small particles (< 0.5 µm).
- Not possess mechanical strength to withstand airflows of the order of 25 lit/s.

Å Use **dense cellulose** paper: Whatman No. 41 (absorb H₂O)
Å **Organic membrane** filter: Millipore, Nucleopore, pallflex, Aerapor (composed of cellulose acetate nitrocellulose)
Fluoropor, Miller: Teflon filter (inert for organic and inorganic)
Filtration

Membrane filter: Study of the sizes and morphology

Glass fiber filter (nonhygroscopic): particles to be collected for measuring their weight.

Organic particulates may dissolved certain synthetic fiber while NO or SO may attack or decompose membrane fiber. For silica, glass fiber filter is not use.

Glass fiber filter: inert to acid and organic solvent
High volume sampler
High volume sampler

Vacuum cleaner type of motor: used to draw a sample through a filter area

Filter: 20 cm X 25 cm mat which allow collection of an air sample at a rate from 18900-28350 cc/s over a sampling period of 4-6 h and normal sample period of 24 h.

1260 ï 2100 m³ of ambient air passes which extract about 0.5 g of suspended particulates.

Motor: Voltage: 220 ï 230 V is usually started and stop by a simple clock timer.

Rotameter: Used to record the volume of sample air passes through filter - μg/ m³
Sampler unit
Collection efficiency of different types of filter media

<table>
<thead>
<tr>
<th>Filter Media</th>
<th>Composition</th>
<th>Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whatman GF/C</td>
<td>Glass fibres</td>
<td>99.9</td>
</tr>
<tr>
<td>Whatman No. 32</td>
<td>Cellulose</td>
<td>99.5</td>
</tr>
<tr>
<td>Whatman No. 42</td>
<td>Cellulose</td>
<td>99.2</td>
</tr>
<tr>
<td>Whatman No. 44</td>
<td>Cellulose</td>
<td>98.6</td>
</tr>
<tr>
<td>Whatman No. 50</td>
<td>Cellulose</td>
<td>97.0</td>
</tr>
<tr>
<td>Gelman Instrument Co., USA Type VM-4</td>
<td>Poly vinyl chloride</td>
<td>100</td>
</tr>
<tr>
<td>Acropor, type AN 3000</td>
<td>Acryl nitrile</td>
<td>99.99</td>
</tr>
<tr>
<td>Type A</td>
<td>Poly vinyl chloride</td>
<td>99.99</td>
</tr>
<tr>
<td>Type E</td>
<td>Co-polymer reinforced with nylon</td>
<td>99.99</td>
</tr>
<tr>
<td>Hollingworth and Vose, USA HV-70, 8-mil</td>
<td>Glass fibre, No organic binder</td>
<td>99.99</td>
</tr>
<tr>
<td>Millipore Filter Corp., USA type HA and AA</td>
<td>Glass fibre with acryl binder</td>
<td>99.99</td>
</tr>
<tr>
<td>Mine Safety Appliance Co., USA Type 1106-B</td>
<td>Cellulose and asbestos</td>
<td>99.9</td>
</tr>
<tr>
<td>Type 1106B</td>
<td>Cellulose esters</td>
<td>99.9</td>
</tr>
<tr>
<td>Schaefer and Scholl, Federal Republic of Germany Ultrafilter</td>
<td>Glass fibre</td>
<td>99.99</td>
</tr>
<tr>
<td>Schneider-poelem, France Type ‘rose’</td>
<td>Flash fired glass fibre</td>
<td>99.97</td>
</tr>
<tr>
<td>Type ‘jaune’</td>
<td>Cellulose ester</td>
<td>99.99</td>
</tr>
<tr>
<td>USSR FFP-15-4.5</td>
<td>Esparto and asbestos fibres</td>
<td>99.98</td>
</tr>
<tr>
<td>FFP-15-3.0</td>
<td>Esparto and asbestos fibres</td>
<td>97.0</td>
</tr>
<tr>
<td>BF AFA RMP</td>
<td>Asbestos and vegetable fibres</td>
<td>99.9</td>
</tr>
<tr>
<td>AFA RMA 20</td>
<td>Asbestos and cellulose fibres</td>
<td>99.9</td>
</tr>
<tr>
<td>US Atomic Energy Commission AEC 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CWS 6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
High volume sampler

Apparatus

1. High volume sampler with flow meter and elapsed time-meter

2. Barometer capable of recording atmospheric pressure to nearest millimeter of mercury

3. Desiccator (50% humidity) to condition the filter

4. Thermometer to record ambient temperatures

5. Glass fiber filters having a collection efficiency of at least 99% for particles of 0.3 µm diameter
High volume sampler

Sampling procedure

1. Check the fiber glass filter for pinholes, particles or other imperfections. Filters with visible imperfections should not be used.

2. Number the filter and equilibrate the filter in the desiccators for 24 hours and weight to the nearest milligram.

3. Record tare weight and filter identification number (do not bend or fold the filter before collection of the sample).

4. Open the shelter of the high volume sampler, loosen the wing nuts and remove the face plate from the filter holder.
High volume sampler

Sampling procedure (cont.)

5. Install a numbered, pre-weighed, glass fiber filter in position (rough side up). Replace the face plate without disturbing the filter and fasten securely (under tightening will allow air leakage and over tightening will damage the rubber gasket). A very light application of talcum powder may be used on the rubber face plate gasket to prevent the filter from sticking.

6. Close the roof of the shelter.

7. Set the on-off timer to start sampling for the prescribed time (24 h), recording the starting time.

8. After five minutes note down the flow rate.
High volume sampler

Sampling procedure (cont.)

9. At the end of the sampling period, record the length of the sampling period (from elapsed time meter) and the flow rate.

10. Remove the face plate as described before and carefully remove the exposed filter without tearing or touching the collected surface. (High winds or inclement weather occasionally make it necessary for the operator to shield the samples with his body or clothing while transferring the filter).

11. Fold the filter lengthwise so that only surfaces with collected particulates are in contact and place in the special folder.
High volume sampler

The mass concentration of the suspended particulates is calculated using the formula

\[ C = \left( \frac{W_2 - W_1}{V} \right) \times 10^6 \]

Where

- \( C \) = mass concentration of suspended particulates in \( \mu g/m^3 \)
- \( W_2 \) = Final weight of the filter in g
- \( W_1 \) = Initial weight of the filter in g
- \( V \) = total volume of air sample in \( m^3 \) at STP
- \( 10^6 \) = conversion of g to \( \mu g \)

\[ V = \frac{(Q_1 + Q_2)}{2} \times T \]

Where

- \( Q_1 \) = Initial flow rate in m/min
- \( Q_2 \) = Final flow rate in m/min
- \( T \) = sampling time in min
**Principle of inertial collection**

- Inertial collectors are designed to give a size representative sample of particles in the atmosphere using the principle that particles in a gas stream are more dense than the fluid (air) in which they are suspended.

- A particle moving in an air stream with approximately the same velocity as the air stream has more momentum (mass $\times$ velocity) than the volume of air that it displaces because of its higher mass.

- The momentum or inertia, possessed by a particle in a moving air stream will cause the particle to be deflected less than the air in the vicinity of the particle when the air stream undergoes a sudden change in stream.
Principle of inertial collection (Cont.)

Å Such a deflection will occur when an obstacle is placed directly in the path of an aerosol stream.

Å If the resulting deflection of the particle from the air trajectory around the obstacle is great enough (large angle of deflection), the particle will strike the obstacle.

Å High incident velocities will increase the momentum of particles in the air stream thereby enhancing their removal.

Å High velocity can be attained by passing the air stream through an orifice (jet) prior to the stream striking the obstacles.
Principle of inertial collection (Cont.)

Å Under the proper conditions, most of the particles within a certain size range that can be made to strike the obstacle will become attached to and remain on the collection surface.
Air stream

Obstacles

Particle collection by impaction
Impaction devices

- Impaction devices collect and retain particles from an aerosol stream on a collecting surface.

- The collecting surface is removed from an instrument and the sample analysis is performed directly on the collecting surface.

- Particle adhesion is caused primarily by electrostatic attraction and by molecular surface phenomena known as Van der waals forces.

- Some loss of large particles occurs with high aerosol velocities.

- The collection surface in many impaction devices is coated with a thin film of oil or light grease to aid in particle retention.
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 \( \mu \).

**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.
Two stage impactor

- The air stream containing the various size particles flows through the first large jet nozzle and impacts on a collection plate oriented perpendicular to the axis of nozzle.

- At the first nozzle exit, the air stream is deflected sharply by the collection plate.

- Large particles continue forward and are collected on the first plate while the smaller particles follow the air stream into the second nozzle which has a smaller jet and higher velocity allowing the smaller particles to be collected on second collection plate.
Two stage impactor

Stage 1 separation
Large jet, low velocity
Large particle collection

Stage 2 separation
Small jet, high velocity
Small particle collection
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
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 μ
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.