CSIR-National Botanical Research Institute (NBRI)

Environmental Information, Awareness, Capacity Building & Livelihood Programme Centre (NBRI-EIACP-PC-RP)

Ministry of Environment, Forest & Climate Change (MoEF&CC)

Government of India (GoI)

CAPACITY BUILDING

as

Hands-On Workshop on Fine Particulate Matter ($PM_{2.5}$) Sampling, Instrumentation and Data Interpretation

to the students of R.D. Memorial Public School, Lucknow on 24th July 2025.

CAPACITY BUILDING PROGRAMME

PM2.5 Analysis: A Comprehensive Workshop on Sampling Techniques, Instrumentation, and Data Interpretation

by NBRI-EIACP Programme Centre, Lucknow

on 24th July 2024

The NBRI-EIACP Centre successfully conducted a capacity-building workshop on "**PM2.5 Analysis: A Comprehensive Workshop on Sampling Techniques, Instrumentation, and Data Interpretation**" to enhance the understanding and skills of participants in the area of air pollution assessment, especially fine particulate matter, for **11 students** of **R.D. Memorial Public School**. Mr. Pradeep Tripathi, Engineer of M/s Envirotech, New Delhi, was the resource person in the workshop. He explained fine particulate matter sampler (APM 550 MMFC) principle and its operations. He effectively disseminated information to all participants through interactive lecture and practical demonstrations on how to use the sampler.

Principle of the Envirotech APM 550 $PM_{2.5}$ Dust Sampler

Fine particulate matter (PM2.5) refers to microscopic particles with an aerodynamic diameter of 2.5 micrometers or less. Due to their small size, these particles can be inhaled deep into the lungs, where they can be absorbed into the bloodstream, posing significant health risks. Therefore, accurate and reliable sampling of PM2.5 is the foundational step in any air quality monitoring program. The Envirotech APM 550 is a manual sampler designed for this purpose, with its core principles based on designs standardized by the U.S. Environmental Protection Agency (USEPA).

The fundamental principle of the APM 550 is to draw a known volume of ambient air through a size-selective inlet and a filter, at a constant, controlled flow rate, over a specific period. The process can be broken down into three main stages:

1. The Inlet and Size-Selective Separation

The first stage involves the sampler's omnidirectional inlet, which ensures a representative sample of air from all directions. The air is then drawn into a two-stage inertial separation system:

- **First Impactor (PM_{10} Separation):** The air stream first passes through an impactor designed to provide an aerodynamic cut-point for particles greater than 10 µm. Particles with high inertia impact on a collection plate and are removed from the air stream. Particles finer than 10 µm continue with the air flow.
- **Second Impactor ($PM_{2.5}$ Separation):** The remaining air, now containing particles smaller than 10 µm, proceeds to a second impactor. This impactor, often a WINS (Well Impactor Ninety-Six) Impactor, has an aerodynamic cut-point at 2.5 µm. Only particles with an aerodynamic diameter of 2.5 µm or less can follow the air stream to the next stage.

2. Particle Collection on a Filter

After passing through the two-stage separation, the air stream containing only PM2.5 particles flows through a 47 mm diameter filter membrane, typically made of Polytetrafluoroethylene (PTFE). PTFE filters are used for their chemical inertness and consistent pore size, making them ideal for gravimetric analysis. The filter traps the fine particles, while a powerful, low-noise, oil-free vacuum pump pulls the clean air through. A key feature of the APM 550 is its two-part cabinet design, which houses the power-dissipating components separately from the filter holder. This ensures that the filter's temperature remains close to ambient temperature, preventing the loss of volatile fractions of the collected particulate matter.

3. Constant Flow and Volume Measurement

A constant volumetric flow rate is critical for accurate size separation and volume measurement. The APM 550 maintains a constant sampling rate of 1 m^3/hr (or 16.7 L/min) using a suitable critical orifice or a microprocessor-based electronic flow controller. This system automatically compensates for changes in pressure drop across the filter as it collects more particles, ensuring the flow rate remains stable. The total volume of air sampled is directly measured and recorded by a dry gas meter or a data logger.

The mass concentration of PM2.5 is calculated as the total mass of particles collected on the filter, divided by the total volume of air sampled. The result is expressed in micrograms per cubic meter (µg/m^3).

Sample Preparation and Metal Analysis

Once the PM2.5 samples have been collected and their mass determined through gravimetric analysis, they can be subjected to further chemical analysis to identify their elemental composition. Metal analysis is particularly important as many heavy metals found in PM2.5 are toxic and can be indicators of specific pollution sources, such as industrial emissions, vehicle exhaust, or waste incineration.

1. Sample Preparation: Acid Digestion

Before metal analysis can be performed, the metals must be extracted from the filter and dissolved into a liquid solution. The most common method for this is **acid digestion**. This destructive process involves:

- **Cutting the Filter:** The exposed filter is carefully cut into smaller pieces to increase the surface area.
- **Adding Reagents:** The filter pieces are placed in a container (e.g., a glass beaker or digestion tube), and a mixture of strong acids, typically nitric acid (HNO_3), is added. Hydrochloric acid (HCl) and other oxidizing agents like hydrogen peroxide (H_2O_2) may also be used depending on the specific metals being targeted and the matrix of the sample.
- **Heating:** The mixture is heated on a hot block or in a microwave-assisted digestion system. This process breaks down the filter and the particulate matter, effectively dissolving the metals into the acid solution.
- **Dilution and Filtration:** After digestion, the resulting solution is cooled, diluted to a known volume with deionized water, and filtered to remove any undissolved particulate matter from the filter itself, preparing it for instrumental analysis.

2. Instrumental Analysis for Trace Metals with ICP-MS

For multi-elemental analysis of digested PM2.5 samples, Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) is the preferred technique due to its superior sensitivity.

- **Principle of ICP-MS:** The liquid sample is first introduced into a high-temperature argon plasma, which effectively ionizes the atoms of the elements present. The resulting positively charged ions are then extracted from the plasma and directed into a mass spectrometer via a series of lenses.

- **Detection:** A mass analyzer (e.g., a quadrupole) separates the ions based on their unique mass-to-charge ratio (m/z). A detector then counts the number of ions for each specific m/z ratio. The number of ions detected is directly proportional to the concentration of that element in the original sample.
- **Detection Limits:** ICP-MS is a highly sensitive technique, capable of detecting elements at ultra-trace levels, often in the parts per trillion (ppt) range. This high sensitivity is crucial for accurately quantifying toxic heavy metals, which are often present in very low concentrations in ambient air samples.

3. Data Interpretation

After instrumental analysis, the raw data must be converted into meaningful concentrations, typically in ng/m^3 or $\mu g/m^3$. This final data can be used to:

- **Identify pollution sources:** Certain metals serve as markers for specific pollution sources (e.g., lead from legacy emissions, or zinc from tire and brake wear).
- **Assess health risks:** The concentrations of toxic metals can be compared to air quality standards to evaluate potential health risks.
- **Study atmospheric transport:** The spatial and temporal distribution of these metals helps scientists understand how pollutants travel and where they impact the environment.

Outcomes:

The workshop successfully achieved its objectives, as evidenced by the following outcomes:

- **Enhanced Awareness:** Participants demonstrated a significantly improved understanding of air pollution and its implications.
- **Knowledge Acquisition:** Participants gained in-depth knowledge of various air pollution indicators and assessment methodologies.
- **Skill Development:** Participants acquired practical skills in PM 2.5 sampling, and data analysis.
- **Hands-on Experience:** Participants gained valuable hands-on experience through practical training sessions.

In this workshop, Dr. Vartika Singh, Information Officer, NBRI-EIACP-PC-RP, provided a comprehensive understanding of key environmental issues related to air quality. The session began with an introduction to air pollution, emphasizing both anthropogenic sources-such as vehicular emissions, industrial discharges, and fossil fuel combustion-and natural contributors.

Mr. Sampurna Nand, Ph.D. Scholar, CSIR-NBRI, Environmental Technologies Division, explained major air quality indicators including $PM_{2.5}$, PM_{10}, NOx, and SOx, with a detailed focus on $PM_{2.5}$ due to its serious health risks and ability to deeply penetrate the lungs and enter the bloodstream. The discussion also covered the health impacts of air pollution, especially on vulnerable groups like children and the elderly, as well as environmental effects such as smog and acid rain.

Dr Sandhya Mishra, Programme Officer, NBRI-EIACP-PC-RP, concluded the session by outlining effective mitigation strategies like clean energy adoption, public transport use, and afforestation. The session was highly interactive and informative, successfully raising awareness among students. Registration was managed by Data Entry Operator Ms. Anamta Nafees Warsi.


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