4.5. MONITORING

Air pollution monitoring activities are typically separated into two classifications: source monitoring and ambient air monitoring. Monitoring can be made directly using continuous measurement instrumentation or manual methods, or remotely using optical sensing systems. Source monitoring involves the measurement of emissions directly from a fixed or mobile emission source, typically in a contained duct, vent, stack or chimney. Stationary source data is used to determine control technology performance, confirm established permit limits are being met, and as input to ozone and/or health risk prediction models. Major stationary sources may have continuous emissions monitors (CEMs) installed to report real-time emissions based on pre-established reporting cycles. Ambient air monitoring involves the measurement of specific pollutants present in an immediate surrounding atmosphere. Most Major urban areas often operate several ambient air monitoring instruments, each dedicated to measuring specific target pollutants.

Ambient Air Monitoring

For ambient air monitoring, specially designed High Volume samplers (HVS) having mass flow controller and cyclone separator are used. These HVS can accommodate both normal size filter paper and a PUF (Poly Urethane Foam) filter fitted at the trunk. High Volume Sampler instruments available in Indian market will require intricate modifications to suit sampling of dioxin and furan from ambient air. Anderson' make Hi-Vol sampler or Dicotomous sampler available in international market are suitable for ambient dioxin monitoring.

Stack/Source Monitoring

For source emission monitoring of dioxin and furan, an intricate flue gas sampling train and procedures are required to be adopted. The integrated stack gas sample is iso-kinetically withdrawn from selected traverse points along the stack cross-section. Semi-volatile organic compounds associated with particulate matter are collected in the front-half components of the sampling train. Semi-volatile organic compounds not collected by high efficiency glass or quartz fiber are adsorbed on porous, polymeric resin, Amberlite XAD-2. The borosilicate or quartz liner, encased in a stainless steel tube is required to perform stack monitoring. This stainless steel tube is capable of maintaining the exit gas temperature at 120 ± 14°C or at required temperature necessary to prevent condensation during sampling.

Air Quality Monitoring

Ambient air quality monitoring carried out at various cities/towns in the country, under National Air Monitoring Programme (NAMP) provide air quality information that form the basis for identifying areas with high air pollution levels and subsequently, for planning the strategies for control and abatement of air pollution. Data generated over the years reveal that Suspended Particulate Matter (SPM) and Respirable Suspended Particulate Matter (RSPM/PM10) exceed permissible levels at many locations, particularly in urban areas. Air pollution problem becomes complex due to multiplicity and complexity of air polluting source mix (e.g. industries, automobiles, generator sets, domestic fuel burning, road side dusts, construction activities, etc.). Ambient air quality monitoring is required to determine the existing quality of air, evaluation of the effectiveness of control programme and to identify areas in need of restoration and their prioritization.

A cost-effective approach for improving air quality in polluted areas involves : (*i*) identification of emission sources; (*ii*) assessment of extent of contribution of these sources to ambient air; (*iii*) prioritization of sources that need to be addressed; (*iv*) evaluation of various options for controlling the sources with regard to feasibility and economic viability; and (*v*) formulation and implementation of appropriate action plans.

Most frequently occurring pollutants in an urban environment are particulate matters (suspended particulate matter *i.e.* SPM and respirable suspended particulate matter *i.e.* RSPM), carbon monoxide (CO), hydrocarbons (HC), sulfur dioxide (SO_2), nitrogen dioxide (NO_2), ozone (O_3) and photochemical oxidants.

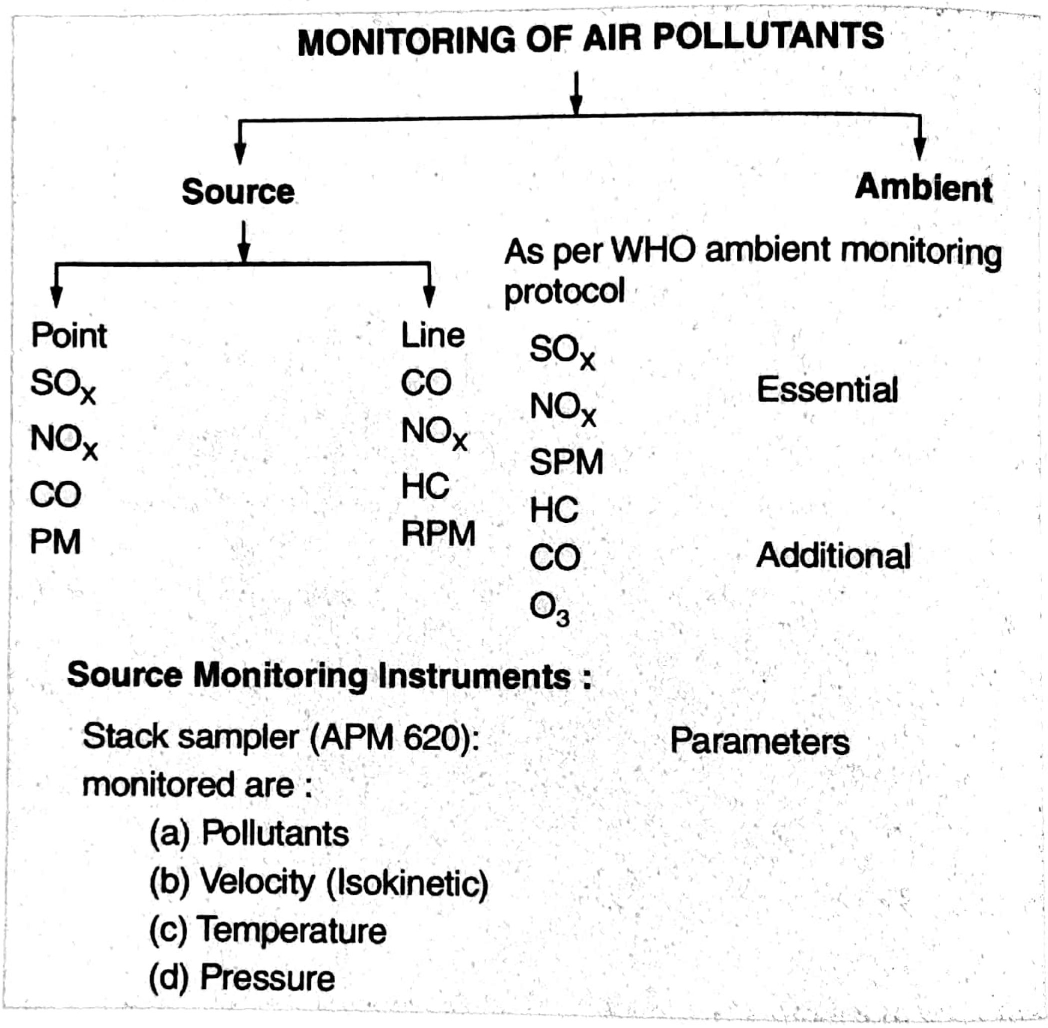

Fig. 4.7. Monitoring of Air Pollutants.

Objectives of Air Quality Monitoring

The major objectives for air quality monitoring are as below:

(i) Background Data

In order to generate background data, air quality monitoring is conducted to assess existing level of contamination and to asses possible effects of air contamination occurring in future.

(ii) Status and Trend Evaluation

The objective is to determine air pollution status and trend information from any continuous air quality monitoring programme. The information is used to determine, whether pollution control strategies as advised by implementing authority are giving acceptable values that is lowering of pollution levels or new or additional control are required to achieve acceptable levels.

(iii) Environment Exposure Level Determination

The air quality monitoring and survey concern itself with systematic study of considerable segment of environment to define inter-relationship of source of pollution, atmospheric parameter and measurable manifestations in order to evaluate the character and magnitude of existing problem.

(iv) Scavenging Behaviour of Environment

To understand natural scavenging or cleansing process undergoing in the environment through pollution dilution, dispersion, wind movement, dry deposition, precipitation and chemical transformation of pollutants generated.

(v) Air Quality Management

To assess the present status to judge effectiveness of air pollution control strategies and long term management of air quality.

The recommended criteria for siting the monitoring stations :

- The site is dependent upon the use/purpose of the results of the monitoring programs.
- The monitoring should be carried out with a purpose of compliance of air quality standards.
- Monitoring must be able to evaluate impacts of new/existing air pollution sources.
- Monitoring must be able to evaluate impacts of hazards due to accidental release of chemicals.
- Monitoring data may be used for research purpose.

Guidelines For Monitoring

For setting up of any ambient air quality monitoring station, the most important thing to be considered prior to commencement of actual monitoring is to collect its background information.

Background Information

The background information that needs to be collected includes details of sources and emissions, health status, demography, population growth, landuse pattern, epidemiological studies. Such prior information will provide immense help to identify the likely effects and in particular health impacts resulting from population exposure to air pollutants.

(i) Sources and Emissions

Sources in a city include vehicles, industries, domestic etc. In an industrial area, information should be obtained on the type of industries including their number, fuel used, composition of fuel, pollutants emitted etc. Information on number and distribution of sources should be collected. This information will help in identifying which pollutants can be expected in an area and thus should be measured. In case of industrial stacks, locations of maximum ground level concentrations should be determined by modeling.

The stations should be located at locations where maximum ground level concentrations are expected. Information on type and number of vehicles should be obtained. Information on domestic fuel that is used in household should be obtained.

Pollution load emanating from these sources should be estimated so as to identify sources that are generating significant amount of pollution.

(ii) Health and Demographic Information

Investigations shall be carried out based on the public complaints received from an area related to air pollution. If the results of such investigations reveal that the level are high that area can be considered for ambient air quality monitoring.

Areas where population density is high (more than one million) can be considered for locating monitoring stations. Information on age and socio-economic status of population is also important for making a decision on initiation of ambient air quality monitoring. Location of monitoring station in such areas will help in finding exposure levels to population which can be used further in epidemiological studies to evaluate health effects of air pollutants.

(iii) Meteorological Information

Meteorological data with respect to temperature, relative humidity, wind speed and direction should be collected. Predominant wind direction plays an important role in determining location of monitoring stations. Due to effects such as land and sea breezes, valley effects etc. it is important to collect local meteorological data specific to the site. The monitoring stations should be located in areas that are downwind from the sources. Mixing height data should also be collected. Mixing height data can be collected from Indian Meteorological Department. Information on duration of various seasons in a year is also important. Measurement frequency should be such that monitoring is done in all the seasons so that all seasonal variations are included in computing annual average.

(iv) Topographical Information

Local winds and stability conditions are affected by topography. In river valleys there is increased tendency of developing inversions. More number of monitoring stations should be located in areas where spatial variations in concentrations is large.

Mountains, hills, water bodies also affect dispersion of pollutants.

(v) *Previous Air Quality Information*

Any previous information collected on ambient air quality can serve as a basis for selecting areas where monitoring should be conducted and previous studies may include data collected for any health studies etc. Previous studies can be used to estimate the magnitude of the problem.

Once the background information is collected, the ambient air quality monitoring is to be initiated and selection of type of pollutant to be measured, number and distribution of monitoring stations etc. should be made.

Selection of Monitoring Location

Principal factors governing the locations of the sampling stations are the objectives, the particular method of instrument used for sampling, resources available, physical access and security against loss and tampering. Air quality monitoring should be done in areas where pollution problem exists or is expected *i.e.* mainly in industrial areas, urban areas, traffic intersections etc. One of the objective of monitoring is to determine status and trends and the air quality monitoring should be done in metropolitan cities and other urban areas so as to compare their levels and determine trends. Selection of site is very important as a incorrect location may result in data that may not meet the objectives of monitoring and will be of limited value. In general the following requirements should be satisfied for site selection.

(a) *Representative Site*

A site is representative if the data generated from the site reflects the concentrations of various pollutants and their variations in the area. The station should be located at a place where interferences are not present or anticipated. In general the following conditions should be met:

1. The site should be away from major pollution sources. The distance depends upon the source, its height and its emissions. The station should be at least 25 m away from domestic chimneys, especially if the chimneys are lower than the sampling point ; with larger sources the distance should be greater (WHO,1977).
2. The site should be away from absorbing surfaces such as absorbing building material. The clearance to be allowed will depend on the absorbing properties of the material for the pollutant in question, but it will normally be at least I m. (WHO, 1977).
3. The objective of monitoring is often to measure trends in air quality and measurements are to be conducted over a long time; thus the site should be selected such that it is expected to remain a representative site over a long time and no landuse changes, rebuildings etc. are foreseen in near future.

The instrument must be located in such a place where free flow of air is available. The instrument should not be located in a confined place, corner or a balcony.

(b) Comparability

For data of different stations to be comparable, the details of each location should be standardised. The following is recommended in IS 5182 (Part 14) 2000

(*i*) On all the sides it should be open, that is the intake should not be within a confined space, in a corner, under or above a balcony.

(*ii*) For traffic pollution monitoring the sampling intake should be 3 m above the street level. The height of 3m is recommended to prevent re-entrainment of particulates from the street, to prevent free passage of pedestrians and to protect the sampling intake from vandalism.

(*iii*) Sampling in the vicinity of unpaved roads and streets results in entrainment of dust into the samplers from the movement of vehicles. Samplers are therefore to be kept at a distance of 200 m from unpaved roads and streets.

(c) Physical Requirement of the Monitoring Site

Following physical aspects of the site must be met :

- The site should be available for a long period of time
- Easy access to the site should be there anytime throughout the year.
- Site sheltering and facilities such as electricity of sufficient rating, water, telephone connection etc. should be available.
- It should be vandal proof and protected from extreme weather highest concentrations and concentration gradients of carbon monoxide are likely to be in the vicinity of roads, highways. The gradients vary in both time and space on the micro and on the neighbourhood scale.

(d) Topographical and Meteorological Factors

Topographical and meteorological factors must also be considered for selecting a monitoring site. The topographical factors that must be considered are mountains, valleys, lakes, oceans and rivers. These factors cause a meteorological phenomena that may affects air pollutants distribution.

Winds caused by daytime heating and nightime cooling may affect pollutant transport causing either buildup of pollutants or dilution. Canyons or valleys may channel the local winds into a particular direction resulting in increase in wind speed. The presence of large water bodies may cause a land-sea breeze wind pattern which may determine pollutant transport. The mountain or hilly terrain may cause precipitation that may affect pollutant concentration.

In general the following requirement may be met for siting the monitoring station.

(*i*) Height of the inlet must be 3 – 10 m above the ground level.

(*ii*) The sampler must be more than 20 m from trees.

(*iii*) Distance of the sampler to any air flow obstacle i.e. buildings, must be more than two times the height of the obstacle above the sampler.

(*iv*) There should be unrestricted airflow in three of four quadrants

(*v*) There should be no nearby furnace or incinerator fumes.

Once a area has been selected for locating a monitoring stations, the site can be selected by finding maximum concentration using air quality modeling.

Modeling refers to the mathematical expression for the fate of pollutants when they are released into the atmosphere taking into consideration the various aspects of atmospheric effects such as dispersion, advection etc. Air quality models are capable of predicting the temporal and spatial distribution of pollutants for a given domain of interest. Air quality modelling can be applied to ground level sources, elevated points sources, line sources, areas sources, flying sources under unlimited mixing, limited mixing, inversion, fumigation, trapping and also on complex terrain, flat terrain and coastal areas. The methodology is different in each case. Maximum ground level concentrations can be calculated where the air quality monitoring station can be located.

Type of Ambient Monitoring Stations

Station type	Description
Type A	Downtown pedestrian exposure station- In central business districts, in congested areas, surrounding by buildings, many pedestrians, average traffic flow > 10000 vehicles per day. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.
Type B	Downtown neighbor hood exposure stations- In central business districts but not congested areas, less high rise buildings, average vehicles < 500 vehicles per day. Typical locations like parks, malls, landscapes areas etc. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.
Type C	Residential population exposure station – In the midst of the residential areas or sub-urban areas but not in central business districts. The station should be more than 100 m away from any street.
Type D	Mesoscale stations – At appropriate height to collect meteorological and air quality data at upper elevation; main purpose to collect the trend of data variations not human exposure.
Type E	Non-urban stations – In remote non-urban areas, no traffic, no industrial activity. Main purpose to monitor trend analysis. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.
Type F	Specialized source survey stations – to determine the impact on air quality at specified location by an air pollution source under scrutiny. Location of station- 0.5 m from curve; height 2.5 to 3.5 m from the ground.

Number of Stations

- Minimum number is three.
- The location is dependent upon the wind rose diagram that gives predominant wind directions and speed.
- One station must be at upstream of predominant wind direction and other two must at downstream pre dominant wind direction.
- More than three stations can also be established depending upon the area of coverage.

Sampling Duration and Frequency

The period and frequency of sampling should be such that statistically reliable averages can be obtained with the data. National Ambient Air Quality Standards states that annual average should be computed of 104 measurements taken twice a week of 24 hours duration. One of the objective of monitoring under NAMP is to determine compliance to the NAAQS so monitoring should be done for 24 hours and minimum 104 days in a year.

The pollutants vary diurnally and seasonally and these variations should be taken into account for determining frequency of sampling. The precision required in the data is also important in determining frequency of sampling. Sampling should be more frequent than the frequency of variation of pollutants.

Particulate matter levels are lower during the monsoon months due to removal by wet deposition. Air pollutants such as CO levels are higher during winter months due to lower mixing heights resulting in less volume of troposphere available for mixing and hence higher concentrations. Thus measurements should be conducted in all the seasons so that in annual average all the seasons are represented equally. In general minimum 20% of the reading should be taken in each season.

Basic Considerations for Sampling

- Sample must be representative in terms of time, location, and conditions to be studied.
- Sample must be large enough for accurate analysis.
- The sampling rate must be such as to provide maximum efficiency of collection.
- Duration of sampling must accurately reflect the fluctuations in pollution levels *i.e.* whether 1-hourly, 4-hourly, 6-hourly, 8-hourly, 24-hourly sampling.
- Continuous sampling is preferred.
- Pollutants must not be altered or modified during collection.

High-Volume Sampler

Monitoring of Particulates in Ambient Air

Air-borne particulate matter is an ensmble of solid particles suspended and dispersed in air. The properties of these particles vary in terms of chemical composition, morphology (size/shape) optical parameters (colour/light scattering), and electrical characteristics (charge, resistance). Particles, which in general are non spherical are classified in terms of their aerodynamic diameter. This is defined as the diameter of a sphere of density (1g/cm^3 having a characteristic same as that of the particle in question.).

In ambient air dust particles have size range from a few nanometer to hundreds of micrometer (μm). In ambient air SPM has bimodal mass distribution with respect to size whose shape depends on the predominant physical and chemical formation processes of particles.

Characteristics for Ambient Air Sampling Systems

Five main characteristicss are :

- Collection efficiency
- Sample stability
- Recovery
- Minimal interference
- Understanding the mechanism of collection

The first three must be 100% efficient. For example, for SO_2, the sorbent should be such that at ambient temperature it may remove the SO_2 from ambient atmosphere 100%. Sample must be stabled during the time between sampling and analysis. Recovery *i.e.* the analysis of particular pollutant must be 100% correct.

Measurement of TSPM and Respirable Particulate Matter (PM_{10}) using High Volume Respirable Dust Sampler Equipped with Cyclone

PM_{10} and TSPM are measured by passing air at flow rate of about 1.1 m^3/min through high efficiency cyclone which retains the dust particles greater then 10 micron size and allow only fines (less than 10 micron particles) to reach the glass microfibre filter where these particles are retained. The instrument provides instantaneous flow rate and the period of operation (on-time) for calculation of air volume passed through the filter.

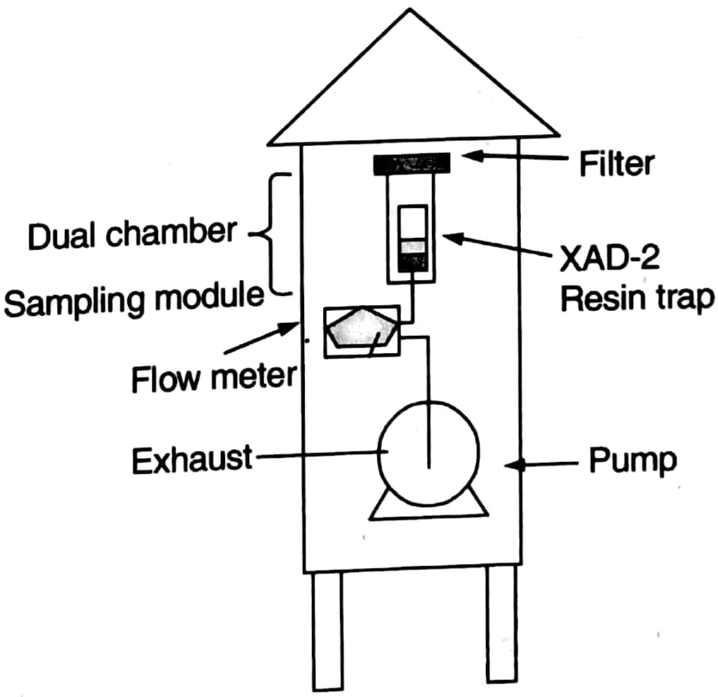

Fig. 4.8. High Volume Sampler

Amount of particulates collected is determined by measuring the change in weight of the cyclone cup and filter paper.

The passage of air entering in the cyclone is designed to prevent heavier settle able particles from reaching in the cyclone.

Selection of Sampling Site

Monitoring site need to be 3-10m high from ground level. This shall result elimination of local activities contribution if any. To get a representative sample the sampler must not be positioned near a wall or other obstruction that would prevent free airflow. In excessively turbulent conditions or in the presence of strong surface winds or otherwise inclement weather, the sampling rate is likely to decrease rapidly and perhaps in a nonlinear fashion due to filter choking. If the sampler is operated continuously, day-to-day variations in the measurement are expected due to varying meteorological conditions and changing atmospheric phenomena, like wind speed and direction, dispersion diffusion, etc. beside impact of emission sources.

Selection of Filter Medium

For most cases interest is limited to a gravimetric determination of the PM10 and total suspended particulate concentration. Glass Micro Fibre filters having low resistance to air flow, low affinity for moisture and 99% collection efficiency for particles of 0.3 microns or larger size are suitable for this purpose. However, where further analysis, of the particulates is to be attempted, to detect specific elements/radicals, care should be taken to choose special filter medium having a low background concentration of the substances of interest.

Preparing the Filter

Prior to use, expose each filter to a light source and inspect for pinholes, particles and other imperfections. Filters with visible defects should not be used. A small brush is often used to remove stray particles adhering to the surface of new filters. Always handle filter papers from their edges and do not crease or fold the filter prior to use.

Filter papers, both blank and containing samples should be conditioned in a desiccator with active desiccant at 20-25°C, humidity below 50% R.H., for at least 16 hours prior to weighing. It is usual to put an identification number and date of sampling on the filters. Weigh the filters to the nearest milligram (accurate up to 0.1 mg for RDS filters and cup) and record the weight and filters identification number in data sheet. Ensure keeping a perforated plastic bottle filled with active silica gel in weighing chamber for minimizing impact of moisture during weighing.

Installation of Filter

Install or remove filter only when the sampler is off. The numbered and the weighed filter is always kept with its rough side up. This increases the collection efficiency of the filter. The filter is placed in its proper position on the top of wire mesh. The sampler is started before putting back the top cover. This prevents the filter to shift from its place.

As a result, any undesirable leakage from top is prevented. The top cover is not to be under tightened as it will give way to leakage and over tightening will damage the rubber gasket and filter. It is not very difficult to ascertain the extent to which the top cover is to be tightened but, one learns through practice only. A very light application of talcum powder on the rubber gasket prevents the filter from sticking to it.

Errors In Sampling by HVS

- Particulates may be lost in sampling manifold – so not too long or too twisted manifold must be used.
- If 'isokinetic' conditioned are not maintained, biased results may be obtained for particulate matters.

Advantages of HVS

- High flow rate at low pressure drop
- High particulate storage capacity
- No moisture regain
- High collection efficiency
- Low coast
- Not appreciable increase in air flow resistance
- Filter is 99% efficient and can collect the particles as fine as 0.3 μm
- Absorption principle is 99% efficient in collecting the gases.