IS 5182-14 (2000): Methods for Measurement of Air Pollution, Part 14: Guidelines for Planning the Sampling of Atmosphere [CHD 32: Environmental Protection and Waste Management]

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(Reaffirmed 2005)

भारतीय मानक

वायु प्रदूषण मापन पद्धतियाँ

भाग 14 वायुमंडल के नमूने लेने की आयोजना के मार्गदर्शी सिद्धान्त

(दूसरा पुनरीक्षण)

Indian Standard

METHODS FOR MEASUREMENT OF AIR POLLUTION

PART 14 GUIDELINES FOR PLANNING THE SAMPLING OF ATMOSPHERE

(Second Revision)

ICS 13.020.40;13.040.20

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FOREWORD

This Indian Standard (Part 14) (Second Revision) was adopted by the Bureau of Indian Standards, after the draft finalized by the Air Environment Protection Sectional Committee had been approved by the Chemical Division Council.

Progress in science and technology has led to situations where constituents of the atmosphere require detection and measurement to meet diverse objectives principally connected with the air pollution.

Detection and measurement of constituents of the atmosphere is becoming increasingly important. Careful planning of measurements is essential to arrive at correct results of the measurement. One of the major factors which influence the representativeness of data collected is the location of monitoring stations. Monitoring stations are set up keeping in view a large number of parameters.

Such a planning requires consideration of various parameters involved in making the measurements, namely, objective, physical access, security, various human and environmental agencies affecting the emission, transport and dispersion of the constituents and their ultimate fate.

The standard takes into consideration, the large number of parameters in setting up monitoring stations. It has been prepared with a view to present broad guidelines to be followed in establishing a monitoring network so as to optimize the efforts. The objectives and situations most likely to be encountered in the country have been considered in detail.

This standard was first published in 1979 and subsequently revised in 1985. The technical committee responsible for the formulation of this standard decided to revise it again. In this revision, the design criteria of a monitoring network for stations beyond 50 km downwind of tall chimneys has been deleted, while various aspects covered in the standard have been carefully examined and modified in accordance with the recent technological developments.

In the preparation of this standard, considerable assistance has been derived from the following publications:

a) Munn (RE). Air pollution problems. Volume 2. The design of air quality monitoring networks, 1981. Macmillan Publishers Ltd, London.

b) World Health Organization (WHO). Air monitoring programme. Design for urban and industrial areas, 1977. Offset Publication No.33, Geneva.

c) Environmental Protection Agency. Guidelines for air quality monitoring and data reporting under ESECA (EPA), 1976. OAQPS No. 1.2-034 Research Triangle Park, North Carolina, USA.

In reporting the result of a test made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values (*revised*)'.

Indian Standard

METHODS FOR MEASUREMENT OF AIR POLLUTION

PART 14 GUIDELINES FOR PLANNING THE SAMPLING OF ATMOSPHERE

(Second Revision)

1 SCOPE

1.1 This standard (Part 14) describes the broad concepts of sampling atmosphere for its constituents other than permanent gases. Details of procedures are not discussed. General principles on which a sampling programme may be planned are given. Guidelines for setting air quality network in a region and in the country are also given.

1.2 This standard specifically considers sampling of ambient atmosphere as distinct from the working environment.

2 REFERENCES

The following standards contain provisions which through reference in this text, constitute provision of this standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

IS No.	*Title*
4167 : 1980	Glossary of terms relating to air pollution *(first revision)*
5182 (Part 5) : 1975	Methods of measurement of air pollution : Part 5 Sampling of gaseous pollution

3 TERMINOLOGY

For the purpose of this standard, definitions given in IS 4167 shall apply.

4 OBJECTIVES OF SAMPLING OF THE ATMOSPHERE

4.1 The strategy for sampling the atmosphere and the extent of a survey are governed by the objectives, which should be defined before planning and undertaking a sampling programme.

4.2 Some commonly encountered objectives for sampling the atmosphere for pollutants are as follows:

a) To determine present conditions and trends;
b) To assess health hazards and potential damage to property;
c) To determine the background pollution levels for application in industrial zoning, town planning or location of sites for certain types of industries requiring stringed air quality criteria;
d) To identify specific industrial and other sources of pollution;
e) To develop and validate air pollution models;
f) To control and monitor pollution from industries to meet air quality standards; and
g) For purely scientific investigations.

NOTE — The objective (g) is outside the scope of this standard.

4.3 An air pollution survey may be limited to a single objective given in **4.2** or may cover more than one. Even if a survey is planned with a single objective, need may also arise to cover some other objectives. Generally, with only a little additional effort it is possible to cover these extra objectives. Whenever such a contingency is foreseen and resources permit, some of these additional objectives may also be considered in planning the survey.

5 PRELIMINARY INFORMATION REQUIRED FOR PLANNING A SURVEY

In addition to the objectives of air sampling programme, it is desirable and sometimes necessary to collect information on qualitative and quantitative data on the local sources of air pollution, topography, population distribution, land use pattern, climatology, etc, depending upon the objectives of the survey. An area map of suitable scale is also helpful. Information should also be gathered on the source of pollution situated at larger distances and which are likely to contribute significantly to pollution of the area under survey. Relevant data regarding physico-chemical behaviour in the atmosphere of the particular pollutant to be sampled should also be collected.

6 GUIDELINES FOR PLANNING A SURVEY

Planning a survey includes planning for the following:

a) Selection of sampling procedures including procedures of analysis of samples;

b) Location of samplers;

c) Period of sampling, frequency of sampling and duration of survey;

d) Auxiliary measurements (including meteorological parameters); and

e) Processing of data.

7 SELECTION OF SAMPLING PROCEDURE

7.1 Several alternatives of instruments and procedures may be available or possible for sampling and measurement of a given constituent of the atmosphere. Broadly, sampling methods and procedures may be classified into two categories, namely, *in-situ* sampling and sampling by remote sensing technique. The *in-situ* sampling may further be sub-classified as in **7.1.1** and **7.1.2.** For other sampling techniques, procedures given in IS 5182 (Part 5) should be followed.

7.1.1 Continuous *in-situ* sampling and measurement of concentration of constituents in air may be made by using optical, spectroscopic, electro-chemical or other methods which are capable of giving a continuous indication and record of concentration (such a system shows rapid or short term variation of the concentration). Long term concentrations may be obtained by conventional procedures of averaging the record or by using electronic or electromechanical integrators.

7.1.2 Time averaged *in-situ* sampling of the atmosphere is carried out by passing a known volume of sample air through or over a trap, a retaining or collecting medium (filter paper or bubbler) or by exposing a collection or reacting surface to atmosphere, for example, sampling of pollen using greased microscope slides or peroxide candles for sulphur dioxide estimates. Occasionally, biological indicators may also be used, for example, lichen exposed to sulphur dioxide.

7.1.2.1 The samples thus collected may then be analysed by established physical, chemical and biological methods to determine their composition from which atmospheric concentrations may be deduced. The concentrations thus obtained are effectively the average over the period of sampling.

7.1.3 *Remote Sensing*

Recent developments in technology especially in laser optics and infrared techniques have made it possible to detect and measure the concentration of several atmospheric pollutants by remote sensing techniques. These have certain advantages over the *in-situ* techniques, the main advantage being that physical access to the location where the measurement is to be made, is not needed. Also, instantaneous space averages of the constituent concentrations may be obtained. These methods are especially useful for sampling of pollutants above ground level and where access becomes difficult or impossible.

7.1.4 The continuous methods are usually expensive. On the other hand, the time average methods are less expensive and simple for operation but require more frequent personal attention and hence need more manpower and ancillary facilities. Also, all information of the fluctuations of concentration overperiods less than the sampling period, as also on the short-term peaks is completely lost. Remote sensing methods are expensive and require sophisticated equipment but are the only methods which do not suffer from constraint of physical access.

7.2 The selection of a sampling procedure depends upon the nature of pollutants, the expected range of their concentrations, and the relevant time average needed for the particular objective. Attention should also be given to ease of operation and sampling under various meteorological and field conditions.

7.2.1 Standard procedures of analysis should be followed. Calibration should be done as frequently as required.

8 LOCATION OF SAMPLING STATIONS

8.1 Some of the 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. Sampling locations may be fixed or mobile. Recommended procedures for *in-situ* sampling are given in **8.1.1** to **8.1.6.** Detailed methods to be adopted in locating monitoring stations are given in **9, 10** and **11**.

8.1.1 When the objective is to study the effects of the presence of a constituent in the atmosphere, namely, health hazards, material damage due to corrosion, etc, the sampling location should be as close as possible to specific locations where the effects are being studied. For example, the most appropriate location for studying health hazards are population centres and certain critical areas, such as hospitals and schools where more vulnerable section of the public is present. The ideal height, at which sampling should be done, is the breathing level.

8.1.2 When the objective is to study material damage, similar principle should be followed. For example, for assessment of damage to vegetation, sampling should be done at foliage level and that for damage to overhead electrical wire should be done at the level of the wires.

8.1.3 When the objective is to determine the background levels of pollution in a given area, an ideal system of location of the samplers is in the form of a grid, which may be rectangular or radial depending upon whether the sources of pollution may be treated as an area source or an effectively single source respectively. The evaluation area is a circle around the centre of emissions, the maximum radius of which is 50 times the stack height. The rectangular grid located entirely within the evaluation area shall be considered. The size of grid shall be 1 × 1 km. Sampling in such a grid should be preferably be done simultaneously at all points or by rotation for a few number of grid points at a time to yield statistically recommended results. The sampler should be located 4 to 12 metres above ground level. No permanent physical obstacle like buildings, trees, etc, should be wholly or partially situated within the space bounded by the right circular cone with its vertex at the collector and opening upwards in a 120° angle. The collector should be located at least one metre above its supporting surface. This system requires considerable amount to effort, resources and manpower.

8.1.3.1 These may however, be appreciably reduced if auxiliary data on location of pollution sources, their emission levels and appropriate meteorological data are available. With this data used in an appropriate model of air pollution transport and dispersion, it is in principle, possible to assess and map the contribution of pollution from the local sources with reasonable degree of accuracy. Simultaneous sampling of atmosphere at locations upwind of such sources also gives the background contribution from sources farther away. Such a system of sampling may also be used to test and improve air pollution models.

8.1.3.2 The minimum number of locations required for such a system depend upon the variability of pollutant concentration over the area under survey. The spatial distribution of the samplers should be such that variation between adjacent sampling locations is sufficient to obtain the corroboration of the dispersion model used or to determine the modification to the model, if necessary, to suit local conditions. Preliminary sampling may be carried out, if necessary, to determine the number and location of such stations.

8.1.3.3 The use of auxiliary data discussed in **8.1.3.1** is essential when mobile stations are used.

8.1.4 When the objective of air sampling is to identify the contribution from specific sources of pollution, the sampling locations should be located in upwind and the downwind of such sources. Recourse to auxiliary data mentioned in **8.1.3** should be taken. The mathematical model based on the topographical and micrometeorological data of the area should be taken into consideration for determining the distance of the sampler from the stack. However, ten stack heights may be used as a guideline distance in case of elevated sources on a flat terrain. Identifying the contribution from specific sources is facilitated if advantage is taken of periods when these sources are temporarily emitting at reduced rates or cease emitting, for example, during shutdown of the plants.

8.1.5 It is important that the sampling equipment is provided with proper security against loss or tampering. Only competent personnel should handle such equipment.

8.1.6 For any objectives other than those given in **4.2**, sampling location should be planned adequately to fulfill that objective as given in **9**, **10** and **11**.

8.2 When remote sensing techniques are used for identification or measurement of constituents in the atmosphere, location of the system or equipment is generally far from the sampling location. Location of a remote sensing system should be such as to give maximum amount of information for which the sampling is planned. This requires consideration of visibility and availability of line of sight between the system and the location at which concentration is to be estimated. Supporting auxiliary data discussed in **8.1.3.1** should also be used where needed.

8.2.1 It is sometimes possible to reduce the number of *in-situ* sampling station if the support of a remote sensing system is available.

8.3 Sampling for Pollution from Vehicular Exhausts

The sampling location, depending upon the objectives, may be located very near the traffic lanes and near traffic signals. Meteorological factors should also be taken into account, where necessary, on lines similar to those discussed earlier.

9 LOCATION OF MONITORING STATIONS

9.0 The location of air quality monitoring stations should satisfy the following conditions:

a) The site should be representative of the area selected;
b) The station should be set up and operated so as to yield data that can be compared with those from stations within the network; and
c) Certain physical requirements should be satisfied at the site.

The ultimate choice for each site is a compromise optimizing these various considerations.

9.1 Representativeness

A representative station's data should reflect concentrations and fluctuations of air pollutants within the given area. In practice, it is not easy to specify the guidelines whether the location of a station is satisfactory or otherwise; however, might be checked by making simultaneous measurements at one or more temporary locations within the area concerned. The stations should not have any interference in the immediate vicinity. The stations should be away from;

a) Nearby sources of air pollution. The suggested distance depend on the height and emission strength of the sources; the station should be at least 25 m away from domestic chimneys, particularly if the chimneys are lower than the sampling point; and larger the source the greater the distance should be;

b) Absorbing surfaces (foliage and absorbing building materials). The clearance to be allowed depends on the absorbing properties of the material for the pollutant in question, but it will generally be at least 1 m; and

c) Area where considerable rebuilding or land use changes are foreseen in the near future, particularly if long term trends are to be observed.

9.1.1 For objectives such as, the study of health effects and the evaluation of damage to vegetation or building materials, or the investigation of specific complaints, the location of sampling stations is considered representative if the data reflects the actual exposure of the receptor. For human exposure, this means that the movements of a population group under study should be covered by several monitoring stations, so as to assess the average exposure.

9.1.2 The measurement of air pollution from motor vehicles requires special attention owing to the sharp concentration gradients likely to be encountered. It may not be necessary at all to have the network stations.

So far as primary pollutants from traffic are concerned (carbon monoxide, nitrogen dioxide, hydrocarbons, lead and smoke from diesel vehicles), maximum concentrations are likely to be found in busy streets, in city centre especially where there are tall buildings on both sides restricting the natural ventilation. If the street is frequently visited by pedestrians, then it may be proper to set up a sampling station nearby, if a suitable site could be found.

9.1.3 A non-homogeneous group of pollutants known as photochemical oxidants, with ozone as the main component, occur in ambient air due to complex reactions between pollutants from traffic in certain atmospheric conditions. As these need time to develop, concentrations of oxidants may be higher at or beyond the periphery of the urban area than within it. This should be taken into account while siting instrumentation for the measurement of oxidant pollutants.

9.2 Comparability

To enable comparison of air quality data from different sites, the details of each location should be standardized as far as possible.

9.2.1 If pollutants emitted from stationary sources are being measured, the sampling intake should preferably be 3 to 4 m above the ground level and 1 to 1.5 m from the nearest vertical or horizontal surface. On all other sides it should be open, that is the intake should not be within a confined space, in a corner, under or above a balcony, etc.

9.2.2 For traffic pollution monitoring the sampling intake should be 3 m above the street level and at a horizontal distance of 1 m from the kerb. Deviations from these specifications are critical and if they have to be made, they should be the same for all stations within a network. The height of 3 m is recommended to prevent re-entrainment of particulates from the street, to permit free passage of pedestrians and to protect the sampling intake from vandalism.

9.2.3 Certain monitoring equipment, for example, high-volume samplers, are to be located outdoors, and for practical reasons these are often located on the roofs of low buildings, caravans, etc. Equipment for monitoring gaseous pollutants, as well as some of the sampling suspended particulate matter, for example, smoke measurement devices, are generally located in special shelters. They are connected by a sampling tube ending with an inverted funnel, which serves to prevent the intake of precipitation and of large particles with the sample air. Sampling in the vicinity of unpaved road 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 metres from unpaved roads and streets.

For sampling suspended particulates the intake flow characteristics (flow rate and funnel diameter) should be standardized and the sampling line should not have sharp bends. It should be as short as possible, preferably not more than 3 m, and made of material which does not react with the pollutant being sampled or release interfering vapours. The diameter of the tube depends on the flow rate and should be standardized for the whole network.

9.3 Physical Requirements

The site where the station is located should fulfill one or more of the following requirements depending on the types of instruments used:

a) it should be available for a long period;

b) it should preferably be accessible any time throughout the year;

c) electrical power of sufficient rating should be available;

d) it should be vandal-proof; and

e) it may need to be protected from extreme of temperatures.

Public buildings are often convenient and are frequently used for the siting monitoring stations.

9.4 Meteorological and Topographical Considerations

The meteorological and topographical features of an area should be critically analysed before selecting a site for a monitoring station. The important topographic features that should be considered are mountains, valleys, rivers, lakes and oceans. Each one of these may cause a particular type of meteorological phenomena which significantly affects the pollutant distribution in an area.

9.4.1 Mountainous/rolling/just slightly sloped terrain may produce katabatic (upslope) and anabatic (down slope) winds. Winds, caused by day time heating and night time cooling may affect the transport of pollutants causing either stagnation or dilution depending on the terrain. The time of onset and intensity of these winds are variable and depend on a number of processes. Canyons or valleys may channel the local winds into a preferred direction flow and may also cause a local increase in wind speed sometimes called a mountain gap wind. Mountainous or hilly terrain can also cause mesoscale precipitation patterns which may affect local pollution concentration through washout. To add to these somewhat predictable patterns, the wind flow over hills, cliffs and valleys may form any of the several patterns depending on the balance on the forces involved.

9.4.2 The presence of large water bodies (lake, sea/ ocean) often cause a land-sea breeze circulation and dominate the local wind patterns. The circulation is variable in strength and extent. Its distance of penetration inland determines the transport of pollutants.

9.4.2.1 Sometimes it is possible that the same polluted air recirculates over an area more than once either from the sea breeze circulation cell or from any wind changes occurring due to a combination of the meteorological features mentioned earlier. An area with a coastline may be affected by coastal stratus clouds which may move some variable distance inland in a diurnal pattern or more back and fourth several times in a day. The localized reduction in radiation or increase in humidity may affect the chemical reactions occurring in the polluted air mass.

9.4.3 The topographical features and consequent meteorological patterns need be taken care of in selecting proper site. It is not possible to stipulate any guidelines for selecting site based on these features, which would apply to all cases. As hills of less than 100 metres height may cause significant wind flow disruptions and as sea breeze may extend tens of kilometres inland even more general site located in relatively flat terrain away from large bodies of water cannot be considered representative without a thorough analysis of the meteorological and topographical features affecting the area.

9.4.4 In addition to the several meteorological and topographical features which need to be considered in site selection there are some broad features above urban mesoclimate which need to be considered. The urban areas affect the atmosphere as they act as heat sources. They are typically warmer during the night and day. This temperature difference can cause weak circulation directed towards the centre of the urban area when not affected by synoptic scale features. The general air flow over an urban area usually has large vertical components than surrounding rural environs and the wind blows at the top of buildings faster and may deviate by more than 30° in direction. These are some of the characteristics of the urban climate which might affect the final site selection.

9.4.5 Within an area chosen for locating a station there are usually many obstructions and some may be even pollution sources. If a general surveillance station is being located, it should not be unduly affected by any specific source. From the diffusion models, it is estimated that the maximum ground level concentrations from a particular source are about ten effective stack heights, downwind. This estimate has been used as rule-of-thumb in specifying that a station be no closer to a particular source that ten effective stack heights. For most cases this is a reasonable criteria.

9.4.6 Obstructions like buildings within an area may also affect the selection of a site. Large buildings influence the air flow and hence care need to be taken to ensure that the samples are taken from a relatively undisturbed air flow. The criteria often quoted for sites that there should not be any obstruction more than 30° above the horizon around the site. The 30° criteria could mean that the site is within the area of the circulating cavity, which is not a representative air stream. Sometimes the building housing the sampling instruments itself may be an obstacle. It is, therefore, essential that sampling probe inlets be above the disturbed air flow.

9.5 Special Techniques to Air in Site Selection

The most common method is 'atmospheric dispersion models' to estimate ground level concentrations. These models are based on a number of assumptions which are rarely applicable to the actual conditions. However, extensive use of dispersion models can be expected to continue. The major defect of such a method is that it gives only an estimate. Actual sampling is essential to test the estimates.

9.5.1 Several agencies are using mobile sampling stations. Their use is restricted to large metropolitan areas or population centres. These stations are moved only once or twice a year and might better be described as semi-permanent stations. Air quality surveillance programme is of three distinct but interrelated elements; sampling networks, laboratory support and data acquisition and analysis.

10 DESIGN OF AN AIR QUALITY SURVEILLANCE NETWORK

10.1 With automatic continuous instrumentation, the need of a laboratory support is considerably reduced, but the problem lies in data transmission, validation and reduction. Network design needs such considerations as the number and types of stations required, their locations, frequency of sampling, and duration of collection period for each sample. The type of network specified for a given region also determines the requirement for laboratory sampling and analytical procedures, laboratory support, and data acquisition and analysis systems.

10.2 The types of networks needed for regional air quality surveillance are:

a) particulate network, and
b) gaseous network.

10.2.1 The particulate network is to be composed primarily of high-volume samplers (Hi-Vols). The Hi-Vols collect total suspended particulate (TSP) which may be fractionated later into trace elements and compounds. The total particulate network design, namely, number and location of Hi-Vols stations, will be determined by the sampling requirements for TSP. The extent to which the Hi-Vol samplers are analyzed for a particular constituent depends upon local conditions.

10.2.2 The gaseous network may be a mixture of mechanized and automatic sampling devices. For some pollutants, such as sulphur dioxide, nitrogen oxides the oxidants, both types of samplers may be used. Where the pollution levels are higher, the urban core network may be composed of automatic sampling stations with the mechanical stations being relegated to areas of lower concentrations between widely spaced automatic stations.

10.3 Information Required for Network Design

Knowledge of the existing pollution levels and patterns within the region are essential in network design. Areas of maximum pollution levels should be defined, together with spatial and temporal variations in the ambient levels. Isopleth distribution of an ambient concentration derived from past sampling and/or from diffusion modelling are best suited to determine the number of stations and suggesting their locations. Additional information on meteorology, topography, population distribution, present and projected land uses and population sources is very helpful in network design. Where isopleth maps are not available, information which can be obtained readily from other organizations involved in such problems provides the basis for initial design.

10.3.1 Where isopleth maps are not available, information of emission densities and/or land use may be used together with windrose data to identify areas of expected higher concentrations. Topographical maps provide additional information on wind flow and pollution dispersion characteristics. Maps of population distribution are essential in locating key stations for monitoring during episodes. In some cases sufficient information for network design is not available, resulting in modification of network when more information and experience are gathered.

10.4 Network Size

The number of sampling stations required depends on the existing levels of pollutants, their variability, and the size of the region. The number of sampling stations should be adequate to allow definition of the area or areas where ambient concentrations are likely to exceed air quality standards. Information on air quality in other areas, including the non-urban portions are also be gathered. A first estimate of the number of stations required in a region may be obtained as a function of total population. This provides minimum and maximum number of stations for each population class depending on the extent and degree of pollutants.

10.5 Methods for Network Design

The general methods for network design are as follows:

a) Modelling methods, and
b) Statistical method.

10.5.1 The principle in the modelling method is that dispersion of pollution can be predicted to a certain extent from a knowledge of emission characteristics and meteorological parameters. It is possible to predict the general pattern of the pollutant concentration field and to arrive at an optimum net work to suit any given monitoring objectives.

10.5.2 The principle of statistical method is that urban air pollution measurements are correlated in space and time. This implies that data obtained from a monitoring network contains a certain degree of redundant information. It is possible in principle, from a knowledge of correlation, to design an optimum network for specific goals.

10.5.2.1 The statistical method pre-supposes the existence of a monitoring network for which time and space correlation fields can be estimated. The modelling method requires, information on source strengths and on the meteorological fields, throughout the city. The best strategy is to combine the two approaches.

When there is an existing network, the optimum number of monitoring stations may be decided either by a distance criteria or by departure of a station mean from the aerial mean or by isopleth distortion. In all these approaches:

a) retain pairs of stations having the smallest gradients,
b) retain pairs of stations having the largest gradients,
c) retain stations with the largest absolute or relative variability, and
d) retain stations with the smallest absolute or relative variability.

10.5.2.2 The most appropriate strategy depends upon the objective of the monitoring programme. The network density decreases with increase in averaging time. The network density appears to have a seasonal variation with fewer stations being required in the summer than in the winter. This is because concentrations of pollution in summer are uniformly low particularly at residential areas thus single station is a good predictor of air quality over a relatively large neighbourhood.

10.5.2.3 Structure functions may also be utilized in the design of network either for meteorological elements or for air pollution.

10.5.2.4 A simple way of determining the relative worth of each station in a network is to compute the statistics of interest, first using all stations and then removing one member in turn. For this purpose the following three different schemes are used:

a) For each actual station the root means square departure interpolated from observed values is computed;
b) For designated grid points the root mean square difference is determined between the interpolated values using all and all but one of the stations; and
c) As in the second scheme except that when the highest ranking station has been chosen that station is removed from the subsequent analysis which then proceeds. This technique could be easily modified to meet related network design criteria, for example, to select a network giving the best estimate of the spatial mean value.

10.5.2.5 Cluster analysis which aims at reducing density with a minimum loss of information is a useful tool. In this the data is divided into classes in ascending ranges of concentrations and constructed a contingency table of the number of occurrences in each class at each station. In places of the table where the number clusters, the space correlation coefficients are relatively high thus providing a practical way of subdividing the network into 3 or 4 sub network each containing stations that are relatively highly correlated within each other. In the next step, analysis is done to determine within each group the station best explained by other members of its group. This station is eliminated and the analysis repeated with the remaining members in group. In case, the remaining members in a subgroup cannot explain more than 85 percent of the variance of the sub-group the process is stoppered arbitrarily.

10.5.2.6 Eigen-vector method may be applied to network design by comparing the maps associated with various sub-networks of stations and selecting the one which causes the smallest reduction in variance.

10.5.2.7 A linear programming optimization model may also be used for designing effective network for various densities of stations. The network effective function is defined as the probability (ranging from 0 to 1) that the pollutant concentration exceeds an air quality standard for a given length of time and that the susceptible fraction of the population is greater than that of some standard population.

10.6 Some Practical Guidelines in Network Design in Urban Area

10.6.1 *Monitoring of Carbon Monoxide*

Highest concentrations and concentration gradients of carbon monoxide are likely in the vicinity of busy streets, tunnels and highways. The gradients vary in both time and space, on the micro and also on the neighbourhood scale. This creates siting problems when monitoring objectives are specified. The recommended criteria for siting monitoring stations are given in Table 1.

10.6.2 *Monitoring of Sulphur Dioxide and Particulate Matters*

10.6.2.1 *Emission from tall chimneys*

If the objective is to detect air quality violations, then the network should be relatively dense. For determining the occurrence of at least one violation per month or per year the design requirements may be relaxed.

10.6.2.2 *Multiple low level sources*

In case of multiple low level sources, the network design is guided by the following:

a) Emission inventory even if it is only subjective,
b) Meso-meteorological wind field in the area,

Table 1 Recommended Criteria for Siting Monitoring Stations

(*Clause* 10.6.1)

Station Type (1)	Description (2)
Type A	**Downtown pedestrian exposure station** Locate station in the central urban area in a congested, downtown street surrounded by buildings where many pedestrians walk. Average daily travel on the street should exceed 10 000 vehicles, with average speed of less than 6.7 m/s. Monitoring probe is to be located 0.5 m from the curb at a height of 3 ± 0.5 m.
Type B	**Downtown neighbourhood exposure station** Locate station in the central urban area but not close to any major street. Specifically, streets with average daily travel exceeding 500 vehicles should be located at least 100 m away from the monitoring station. Typical locations are parks, malls, or landscaped areas having no traffic. Probe height is to be 3 ± 0.5 m above the ground.
Type C	**Residential station** Locate station in the midst of a residential or sub-urban area. Station should be more than 100 m away from any street having a traffic volume in excess of 500 vehicles/day. Station probe height must be 3 ± 0.5 m.
Type D	**Mesoscale station** Locate station in the urban area at appropriate height to collect meteorological and air quality data at upper elevations. The purpose of this station is not to monitor human exposure but to gather trend data and meteorological data at various heights. Typical locations are tall buildings and broadcasting towers. The height of the probe, along with the nature of the station location, must be carefully documented in each case.
Type E	**Non-urban station** Locate station in a remote, non-urban area having no traffic and no industrial activity. The purpose of this station is to monitor for trend analysis for non-degradation assessments, and for large-scale geographical surveys, the location or height must not be changed during the period over which the trend is examined. The height of the probe must be documented in each case. A suitable height is 3 ± 0.5 m.
Type F	**Specialized source survey station** Locate station very near a particular air pollution source scrutiny. The purpose of the station is to determine the impact on air quality, at specified locations, of a particular emission source of interest. Station probe height should be 3 ± 0.5 m unless special considerations of the survey require a non-uniform height.

c) Topography,

d) Population,

e) Projected land use changes, and

f) Budget constraints.

For health related studies, particulate sampling should also, if possible include measurements of size distribution.

10.7 Rule of Thumb on Network Density

Two empirical methods for estimation network density are well known; one based on population, the other based on area and the present level of pollution in the region.

10.7.1 *Criterion Based on Population*

A nomogram relating numbers of stations to population is given in **10.7.2.1** and **10.7.2.2**. In cities where emission of particular pollutants are small, network density may be considerably reduced.

10.7.2 *Criterion Based on Concentrations and Area*

The total number of samples N required for a given region may be estimated from the following empirical relation:

$$N = N_x + N_y - N_z$$

where x, y and z refer to areas of dimensions x, y, z in km² in which pollution levels are respectively higher than the annual air quality standards, intermediate between air quality standards and background levels, and at background levels respectively. The values of N are given as follows:

$$N_x = 0.0965 \frac{C_m - C_s}{C_s} x$$

$$N_y = 0.009\,6\ \frac{C_s - C_b}{C_s}\ y$$

$$N_z = 0.000\,4\,z$$

where

C_m = numerical value of the maximum isopleth, to the nearest 10 µg/m^3,

C_s = ambient air quality standard (µg/m^3); and

C_b = numerical value of the minimum isopleth, again to the nearest 10 µg/m^3.

The above equations apply well to sulphur dioxide and suspended particulate matter.

10.7.2.1 For generating background data on the ambient air quality around the proposed site of a development project, ambient air quality monitoring is necessary. The agencies assigned with this job often face difficulties in deciding the number of stations where such data should be collected to yield representative results of the area. In fact, the more are the number of stations and the more is the frequency of monitoring, the better is the result. However, resources constraints do not permit to monitor at a very large number of stations and hence an optimization is called for:

Frequency

- 3 seasons a year (excluding monsoon)
- 4 weeks per season
- Twice a week

Duration

- For SPM – 3 × 8 hourly samples per day
- For SO_2 – 6 × 4 hourly samples per day
- For NO_2 – 6 × 4 hourly samples per day
- For CO – 4 hourly grab samples for 24 hours (*see* Note)
- For Oxidants – 4 hourly grab samples for 24 hours (*see* Note)

NOTE— If CO and oxidants are monitored by installing direct indicating type monitoring devices at sites, 3 eight-hourly sampling can be taken.

10.7.2.2 Recommended minimum number of monitoring stations in urban areas of given population is given in Table 2.

10.7.3 When proposal relates to air quality trend analysis, the main criteria for network density is population. A city with population of 0.5 to 1 million should have 5 to 10 monitoring stations distributed so that one station represents 10 to 20 km^2. In cities with large number of population with complex topography or with an unusually large large number of pollution sources one station per 5 to 10 km^2 is suggested.

11 URBAN REFERENCE STATIONS

An urban reference station is an air quality/meteorological station located within an urban area but not near sources of population or obstruction to the wind. Suitable location could be found in larger parts. The purpose of establishing such stations is to assist on the estimation of long term trends in urban air quality and climate, and/or to study the transport and diffusion of plumes from tall chimneys within the metropolitan area but away from the disturbing effects of urban building and canyons.

Table 2 Recommended Minimum Number of Stations, Population-Wise

(*Clause* 10.7.2.2)

Pollutant	Population of Evaluation Area	Minimum No. of AAQ Monitoring Station
(1)	(2)	(3)
SPM (Hi-Vol)	< 100 000	4
	100 000 - 1 000 000	4 + 0.6 per 100 000 population
	1 000 000 - 5 000 000	7.5 + 0.25 per 100 000 population
	>5 000 000	12 + 0.16 per 100 000 population
SO_2 (Bubbler)	<100 000	3
	100 000 - 1 000 000	2.5+0.5 per 100 000 population
	1 000 000 - 10 000 000	6 + 0.15 per 100 000 population
	> 10 000 000	20
NO_2 (Bubbler)	<100 000	4
	100 000 - 1 000 000	4 + 0.6 per 100 000 population
	>1 000 000	10
CO	<100 000	1
	100 000 - 5 000 000	1 + 0.15 per 100 000 population
	>5 000 000	6 + 0.05 per 100 000 population
Oxidants	- do -	- do -

12 PERIOD, FREQUENCY AND DURATION OF SAMPLING

12.1 The term period of sampling used in this standard refers to the length of time over which a single sample or a set of samples is collected with the intention of obtaining an estimate of average concentration of the constituent under study, over that period. When a continuous sampler is used it refers to the time interval over which the continuous record is averaged. The term frequency of sampling reference to the number of times samples are collected during a given time. It is implied that the samples are evenly spaced in time. For example, samples may be collected with a sampling period of three hours and a frequency of 8 times a day consecutively or 6 times a day with one hour gap, between consecutive samples.

Duration of sampling is the total length of time for which the entire sampling programme is carried, namely, duration of sampling may be one year to cover all seasons or may be only one week for some specific objectives.

12.2 The period, frequency and duration of sampling should be appropriate to the objective of the study. The meteorological and source emission factors which influence the atmospheric concentrations should be taken into account. Some of the meteorological factors, influencing the period, frequency and durations are predominance of certain with directions in different seasons, diurnal variation of wind speed, direction and stability parameters. The period of sampling should also be such that measurable quantities of the constituent are trapped in the sample at the end of the sampling. It is often preferable to observe sampling periods consistent with those averaging times for which air quality criteria of the given pollutant are specified.

The period and frequency of sampling should be such that statistically reliable averages over larger periods or over the duration of sampling may be obtained from the data. For example, one 24-h sample collected daily, once weekly and once monthly respectively will give increasingly unreliable estimates of an annual average. The reliability will be further questionable if the sampling frequency is not uniform but biased towards certain seasons.

12.2.1 It is sometimes possible to reduce the bias and in fact reduce the overall extent of sampling with the help of the knowledge of local diffusion climatology and a reliable pollution model and knowledge of statistical behaviour of air pollution data.

12.2.2 The period, frequency and duration of sampling should also take into account the physico-chemical or biological processes in the atmosphere, namely, formation and decay of photochemical smog or release of pollen or certain other aeroallergens may be enhanced in certain periods only.

12.2.3 Comparison of data from different sampling periods should not be done unless suitable correction factors for the differing sampling periods are made.

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