Ambient Air Sampling Approaches

(Extract from Gov.uk website)

Omnidirectional sampling or directional sampling

Very often, ambient air quality surveys are designed to assess the impact of a particular process, works or site. If sampling is carried out from all directions or under all wind directions (omnidirectional sampling), then the direction of the wind must be taken into account when the data are assessed. Alternatively the sampling itself may be designed to be directional: gases or suspended particulates would then usually be collected by an active sampling system linked to a wind vane and anemometer. Sampling only occurs when the wind is blowing from a specified direction and is above a minimum wind speed.

Directional samplers are most useful when there is a clearly defined suspected source of the pollutant and the background air concentration is expected to be low in comparison. In such cases a single directional sampler, located downwind of the source for an appropriate duration, would be expected to give a good estimate of that source's contribution. It can be an advantage to use a directional sampler with two wind-vane-operated sampling receptors, one receiving sample when the wind arrives from the narrow direction of the source, and the other receiving sample all the remaining times.

Most active directional apparatus samples from a pre-selected wind direction arc of say 30 to 70 degrees that has the axis of interest as its centre line. The distance from the source should be chosen to allow an acceptance arc in this range to be used, whilst at the same time taking account of the type of source: for example, the plume from an elevated source (stack) is expected to reach ground level after a downwind distance equivalent to between 10 and 20 times the stack height (although a more accurate estimation can be obtained from atmospheric dispersion modelling studies). Emissions from any other interfering pollution sources within the acceptance arc will lead to an overestimation of the contribution of the targeted source of interest. On the other hand, if there are other sources that lie outside the acceptance arc then their contribution will be considered part of the background concentration. These situations can be minimised by carefully choosing the most suitable sampling distance from the suspected source in conjunction with an appropriate acceptance arc. If this is not sufficient, several directional samplers can be positioned in different directions around the works to obtain an integrated value of the contribution of the targeted source relative to that of other sources and the general background[6-8]. Alternatively, directionally-resolving equipment such as the Rupprecht & Patashnick ACCU System can be set up to sample from three or more wind sectors.

Fixed-point sampling or open path methods

The most common sampling system is that of a network of sites at fixed locations, each providing instantaneous spot-concentration values or time-averaged concentrations from a fixed point in space. The success of a fixed network of *in-situ* samplers will be largely dependent on the care with which the sites are chosen in regard to the survey objectives..

Open path measurement techniques allow measurements to be made directly in the atmosphere without obtaining samples. The average concentration of a specifically targeted pollutant is determined over an extended measurement path, rather than at a localised point. Some methods allow the concentration to be spatially resolved. Others give the average concentration over the whole path length, which finds application in assessing the transfer of pollutants across site boundaries and along roads and runways, but the difficulty of interpreting integrated-path data should be recognised. Differential optical absorption spectroscopy (DOAS) instruments such as OPSIS use a double-ended system which measures the average concentration between the instrument and a reflector up to hundreds of metres away. The system is able to measure many common pollutants including SO_2, NO, NO_2, H_2S, O_3, benzene, toluene, xylenes and formaldehyde. Laser interferometry detection and ranging (LIDAR) can measure aerosol particles, and differential absorption LIDAR (DIAL) is able to carry out range-resolved measurements of specific pollutants (e.g. SO_2, NO_2, O_3) over several kilometres by analysing backscattered laser radiation. LIDAR and DIAL are particularly suitable for producing two-dimensional or three-dimensional maps of pollutant concentrations over large areas such as industrial complexes. Measurement by open path techniques tends to be expensive because of the complexity and sophistication of the equipment and data handling facilities.

Open path methods lend themselves to mobile sampling: this may be vehicle-mounted instruments for carrying out measurements at a large number of locations, or for measuring the pollution concentration profile along a given route. Systematic traversing of a plume emitted from an elevated point source is an application well suited to mobile monitoring systems but, because meandering of the plume tends to distort the pattern, each traverse gives only an approximation to the instantaneous cross-wind spread of the plume and several hours of sampling are required to define the plume envelope in a way that could be related to patterns observed from fixed networks. Airborne systems using *in-situ* continuous analysers have been used for some specialist applications, such as tracking power station plumes across the North Sea. Such systems have the advantage of greater freedom of movement, three-dimensional capability and higher speed of traverse, but are of course so expensive as to be only justified for specialist investigations.

Choice of measuring method

For many pollutants, a reference method will have been stipulated which must used in order to comply with standards, thus reducing or eliminating any choice of measuring method. However, where no stipulated or best practice method is applicable, the general principles to consider are outlined in the following sections.

Method Performance

Wherever possible, MCERTS certified instruments should be chosen. MCERTS is the Environment Agency's Monitoring Certification Scheme. The MCERTS performance standards for continuous ambient air-quality monitoring systems (CAMs) have been defined so that MCERTS-certified CAMS will be capable of meeting the requirements of Directive 2008/50/EC of the European Parliament and of the Council of 21 May 2008 on ambient air quality and cleaner air for Europe. The pollutants covered include nitrogen monoxide (NO), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), particulate matter (PM10 and PM2.5), benzene and benzene-like VOCs.

If an MCERTS-certified CAM cannot be used for the study, the following method performance characteristics should be considered when determining how well a method is suited to a particular application:

Method sensitivity. This is the amount of indication (the response) produced per amount of air pollutant sampled. For a direct-reading continuous analyser this may be the signal output in millivolts per unit concentration air pollutant. For an integrating wet method, this may be the amount of titrant needed per unit concentration air pollutant to indicate the end-point in an absorbent solution. A highly sensitive method is needed if it is required to measure small changes in air pollutant concentrations. Note that these small changes may be at low or at high concentration levels.

Limits of detection and measurement range. For a method of a given sensitivity, there will be a minimum air pollutant concentration that will produce a measurable response. This is the lower detection limit (LDL) and is influenced by the level of background noise signal or the magnitude and variability of blank values. The method should also produce a linear or other known response to the air pollutant concentration over a particular range. For an instrumental method, there is often one measuring range or it may be possible to switch between a number of alternative measuring ranges. For indirect methods, sufficient sample is collected to enable the analytical end method to be used in its measurement range. The range is effectively altered by varying the amount of air sampled (by altering the sampling flow rate or by altering the duration of sampling) and hence the amount of pollutant collected. However, consideration must also be given to the measurement average time required.

Speed of response. This is most relevant for direct-reading instrumental methods, especially when measurements over short averaging periods are required. The instrument must be capable of responding to the pollutant with sufficient speed to enable the pollutant concentration peaks and troughs of interest to be resolved.

Selectivity and specificity. The measurement method should be specific for the pollutant of interest, or be selective enough to distinguish and quantify the pollutants of interest from unwanted species. At times it may be desirable to monitor with a non-specific method that measures a group of compounds that have similar chemical properties, e.g. the acidimetric method of measuring net gaseous acidity in air samples, which is expressed as the equivalent concentration of SO_2.

Susceptibility to interferences. There are species other than those of interest that could potentially affect the measurement result, giving either a positive or a negative interference. Examples are the presence of water vapour in many infrared analyses, and the presence of organic acids when analysing fluoride by ion chromatography. For samples collected for later analysis, the stability of the sample is important.

Accuracy and precision. Many of the previously mentioned method characteristics have an influence on either the precision or the accuracy, or both. The *overall uncertainty U* (or, as it is more properly known, the *combined uncertainty*) of the result given by an apparatus or a measuring procedure is the estimate of the range of values that the 'true' value can be expected to fall within. It combines in a single value both the *precision* − the degree of agreement between the successive measurements – and *accuracy* – how close the measurement is to the "true" value. The combined uncertainty is conventionally expressed at a confidence level of 95% in the form:

$$\text{(Result): } X \pm U \text{ (units)}$$

For example: nitrogen oxides concentration = 500 ± 35 ppm.

The *repeatability* (r) for any single result is given by the standard deviation (s) multiplied by the value of the mathematical function known as Student`s t (obtained from t-tables) appropriate for that (large) number (n) of repeats at 95% confidence limits:

$$r = t.s$$

The *bias* (*d*) is the difference between the mean (*x*) of the results and the accepted true" value (μ) of the reference gas:

$$d = x - \mu$$

The *uncertainty* (*U*) is the combination of the random and systematic errors:

$$U = d + r$$

General guidance has been published by the International Standards Organisation (ISO), as well as guidance, on estimation of uncertainty for analytical measurements and specific guidance on certain aspects of air quality measurements

Reliability and unattended operation. Methods vary in the degree of manual operation and continuing attention they require. For example, direct-reading continuous analysers can require frequent calibration; indirect methods may require renewal of reagents.

These considerations, and the overall reliability of the method, can be more or less important depending on the type of monitoring programme. Long-term reliability and unattended operation would be of crucial importance in a network of monitoring sites at remote locations, but may be less important for a short-term survey close to the laboratory.

Other Considerations

Table 1. Other factors which may influence the choice of monitoring method.

Cost	One factor in the choice of measurement method to be used is the resources available, both financial and human. There are wide variations in the capital costs and running costs of different measurement methods. Some simple, inexpensive apparatus can be labour-intensive when used for extended durations and may incur additional analysis costs. Automated monitoring equipment is available for unattended operation but the capital costs are usually higher and ongoing running and maintenance costs must be met.
Method complexity	The availability of technical staff who have the necessary experience, or who could be trained, is a factor to be considered when selecting an appropriate method. Manual methods, for example diffusion tube sampling are less complex than direct reading continuous analysers, which can require a higher degree of ability in the event of operational failure. However, even with simpler methods it is important that adequate training and instruction is given.
Manufacturer support	This is especially relevant for instrumental techniques. Important considerations here are: the extent of back-up available from manufacturers in the event of equipment malfunction; the availability and delivery of consumable items and spares; the turn-around time for servicing and repairs; and the provision of replacement instruments if some have to be taken out of service.

Portability and size	Generally, the simpler, cheaper methods tend to be more portable than the more expensive, complex methods and can be very useful for obtaining a large number of samples in a short time. Continuous analysers in particular can be quite heavy and bulky and may also require a warm-up time of several hours before monitoring can start. The exceptions are some remote methods, which tend to be very expensive but are designed to be mobile.
Practical requirements	Some monitoring apparatus is designed to be operated in the open air. However, many instruments require some sort of housing to provide shelter, weatherproofing and security. Some apparatus need very few facilities, if any at all, e.g. deposit gauges, dust slides, diffusion tubes. Other apparatus need much more, and a site containing a number of direct-reading continuous analysers will require a secure housing, air conditioning and an electricity supply.

Reference: Environment Agency (2011) Technical Guidance Note (Monitoring) Monitoring Ambient Air. Environment Agency. Version 2. May 2011
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