When to sample, how long to sample for, and how many samples to take

(Extract from Gov.uk website)

General considerations

Three separate issues need to be considered:

- the duration of the whole sampling programme
- whether continuous monitoring is required or intermittent sampling can be carried out
- what the averaging period will be over which an individual measurement is made (for intermittent sampling) or the data are to be expressed (continuous or intermittent sampling).

When monitoring is for comparison with certain air quality standards or objectives, these parameters may already be specified. In other cases the decisions will need to be based on how the pollutant concentration is expected to vary with time, the nature of the effects of the pollutant and the characteristics of the monitoring methods available.

Continuous or intermittent sampling

The expected short-term variability in pollutant concentrations determines whether it is necessary to sample continuously to accurately characterise air quality, or whether it is possible to sample intermittently. If pollutant levels vary so frequently and significantly that intermittent sampling periods are not likely to be representative of the study period as a whole, then sampling must be carried out continuously. Continuous sampling does not necessarily mean using direct-reading real-time analysers; it is possible to sample continuously using non-direct-reading manual sampling methods with longer sample averaging periods. For example, continuous daily-average concentrations of black smoke and sulphur dioxide were measured for many years using eight-port bubbler sampling apparatus with a subsequent laboratory analysis stage.

If intermittent sampling is carried out then one must consider how long it is necessary to sample for and how many samples to take. This is linked to the averaging period over which the measurements are eventually to be reported (see Section 7.3). If measurements are being made for comparison with a particular air quality standard then it is necessary to take into account the averaging time of that standard. Ideally the duration of each sample should not be greater than the averaging period over which it is expected to be expressed. The duration of individual samples forming part of a continuous measurement may be considerably smaller than the averaging time required for the results, and this may be because the measurement method has performance limits (e.g. sample saturation, sample breakthrough) that make this necessary, or because the air quality standard has been defined in this way. For example an air quality standard may be expressed as an annual-average concentration calculated from daily (24-hour) samples.

Two approaches to scheduling intermittent sampling have been described. The modified random system commonly used in air sampling networks, calls for sampling intervals of fixed length, e.g. weekly. During this sampling interval, one day is randomly chosen for sampling. The alternative approach, the systematic approach, calls for starting the sampling programme on a day picked at random, followed by sampling at fixed intervals, other than seven days, from that day onward. The systematic approach appeared to display a better relative precision.

For soil or herbage measurements, individual samples are of course obtained virtually instantaneously, rather than over a distinct averaging period. Nevertheless, many pollutants are accumulated by vegetation over periods of days or weeks, and the sampling frequency of herbage should take into account the expected accumulation time. To characterise large temporal variations it is necessary to carry out frequent sampling, to enable both the peak concentrations and longer-term concentrations to be defined.

The averaging period

The wide choice of monitoring methods available is accompanied by a similarly wide choice of time periods that can be used for measurements. The aims or objectives of the study may in some circumstances unambiguously define the averaging time. This is the case for monitoring to assess compliance with EU Directive Limit Values, since the averaging time is specified along with the limit concentration. Examples of National Air Quality Standards published in the UK National Air Quality Strategy, and their associated averaging times, are shown in Table 1.

When the averaging period has not already been fixed, it must be decided upon by taking into account the expected short-term variability in pollutant concentrations and whether such peaks are of importance. Consider the receptor of concern and how long that receptor needs to be exposed for in order to experience possible harm. Pollutants having acute health effects are generally measured over short averaging periods.

Table 1: Examples of National Air Quality Standards for England & Wales

Pollutant	Standard Concentration	Measured as
Benzene	5 μg/m^3	annual mean
1,3-butadiene	2.25 μg/m^3	running annual mean
Carbon monoxide	10 μg/m^3	maximum daily running 8-hour mean
Lead	0.25 μg/m^3	annual mean
Nitrogen dioxide	200 μg/m^3	1 hour mean
	40 μg/m^3	annual mean
Particulates PM10	50 μg/m^3	running 24-hour mean
Particulates PM2.5	25 μg/m^3	annual mean
Sulphur dioxide	266 μg/m^3	15-minute mean

For example, sulphur dioxide has a major impact on receptor organisms over short-term high-concentration episodes and hence mainly short-period, high-frequency information is relevant. An example at the other end of the scale is lead, which has a long-term cumulative effect making short-term peaks much less important. This is reflected in the long averaging period that applies to the air quality standards for lead. Some pollutants have more than one averaging time of interest because they adversely affect more than one type of receptor and these different adverse effects occur over different periods of time. For example, nitrogen dioxide has a 1-hour standard to protect human health and an annual standard to protect ecosystems. Table 2 gives some recommended averaging times for selected applications.

Table 2: Suggested averaging times for different studies

Order of minimum averaging period	*Type of survey*
10 s	Odour assessment; mobile sensors; acute respiratory effects; studies of puffs
3 min	Useful for studying odours and acute health effects if faster response not available
1 h	Time average concentrations; dispersion studies; diurnal changes; discrete source studies; damage to plants
24 h	Chronic health effects; area source studies; effects of weather systems; effects on different days of the week
1 month	Seasonal and annual variation; long-term effects from global source

Sampling for odours is a special case. Odours resulting from factory stack emissions are often perceived for only a few seconds at a time, when atmospheric turbulence causes the undulating plume to reach ground level. Sampling to assess odours must be carried out over similarly short averaging periods if these intermittent peaks are to be resolved.

If the objective of the study is to verify or support predicted ground-level concentrations made by computer dispersion modelling, then the latter concentration predictions should themselves have been made using an appropriate averaging time and of course the same averaging time should be used in the follow-up monitoring survey.

The chosen averaging period may limit the choice of measuring techniques and vice versa, as some methods may only be capable of operating within a finite range of sampling averaging times. This is particularly true for non-continuous methods having an associated analytical end-method stage, for which a sufficient mass of pollutant must be sampled to achieve an adequate lower detection limit. The mass sampled is dependent on the pollutant flux to the sampler. The determining factor becomes the sampling time, not only for diffusive sampling, but also for active sampling since the sampling flow rate is usually constant. The response time or sampling time of the method should be considered in relation to the required averaging period. Very often the choice will be between a direct-reading continuous method providing a vast quantity of data with a very fine time resolution, and less expensive, indirect manual methods. The latter may be used to sample virtually continuously and are perfectly adequate for many applications. A notable example is the widespread use of NO_2 diffusion tubes, which are usually exposed for about two weeks, but application of an empirical factor to the results enables an estimate of the 98th percentile of hourly means to be obtained. When logging data from a continuous method, it should be noted that the shorter the averaging period, the greater the volume of data collected i.e. an averaging period of one minute will produce 60 data points per hour, compared with 12 data points per hour if 5 minute averages are logged. This means that the data storage capacity of the logger is reached over a much shorter monitoring period. It is also difficult to look at very large datasets e.g. a year’s data in one minute resolution, and some spreadsheet functions cannot cope with this volume of data.

Duration of the sampling programme

Pollutant concentrations are significantly affected by temporal variability, such as: seasonal variations and diurnal cycles in meteorological conditions and emission patterns; weekday/weekend differences; and longer-term variations in, for example, production/manufacturing, fuel usage, etc. Therefore, short-duration sampling programmes are unlikely to give data that cover these different variations, so that they may be unrepresentative. Short-term peaks may be unusual events occurring on only a few days in each year (Figure 1) and if these episodes are of interest, an extended monitoring period may be required to capture them. Short-duration programmes aimed at episode identification (particularly from elevated point sources) rely on an element of luck and often large expenditure can result in meagre success.

It follows that a monitoring survey of a full year or more is ideally required to take account of the full range of the above variables, although a shorter survey that aims to include an equal number of summer and winter months can sometimes provide a reasonable and more cost-effective estimate. What constitutes a suitable survey duration will also depend on the measurement method used, particularly the sampling duration and frequency. It has been suggested4 that if intermittent sampling is conducted weekly, it will be necessary to sample over a period of not less than three months to obtain a representative annual average concentration

In general, long sampling programmes are preferable when comparisons are being made with long-term air quality standards. Figure 2 shows the relationship between mean NO2 calculated from monthly data compared to the mean value obtained from annual data.

Figure 1: Number of days of poor air quality (NO_2 exceeding 100 ppb) at AURN sites in 2009

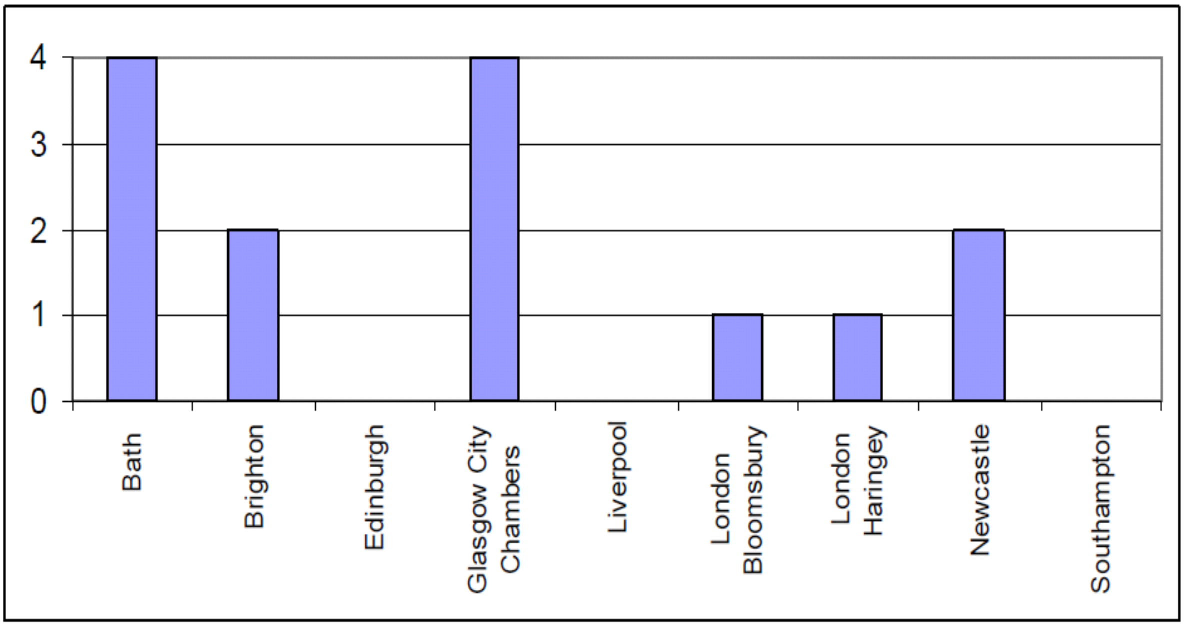
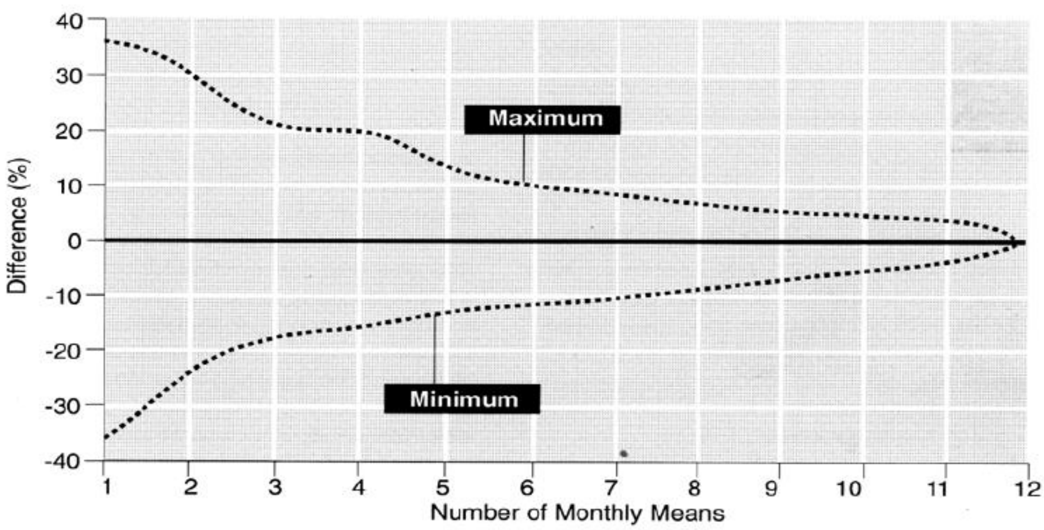


Figure 2: True NO_2 annual mean compared to averages over different monthly means



Reference:

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https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/301188/TGN_M8_Monitoring_Ambient_Air.pdf

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