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Guidance

Monitoring ambient air: monitoring strategy

How to develop monitoring strategies for assessing levels of pollutants in the ambient atmosphere.

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Contents

1. Introduction

You must identify the aims and objectives of an ambient air quality monitoring survey and develop a monitoring strategy to make sure you meet these objectives. This document discusses the factors that you must consider when developing the monitoring strategy, with some suggested approaches to specific types of survey. It gives guidance on the handling, analysis, interpretation, and reporting of air quality monitoring data.

Five further ambient air monitoring guides give supplementary information to this strategy guide:

- Monitoring ambient air: particulate matter (https://www.gov.uk/guidance/monitoring-ambient-air-particulate-matter)
- Monitoring ambient air: data analysis techniques (https://www.gov.uk/guidance/monitoring-ambient-air-data-analysis-techniques)
- Monitoring ambient air: quality control and quality assurance (https://www.gov.uk/guidance/monitoring-ambient-air-quality-control-and-quality-assurance)
- Monitoring ambient air: choosing a monitoring technique and method (https://www.gov.uk/guidance/monitoring-ambient-air-choosing-a-monitoring-technique-and-method)
- Monitoring ambient air: techniques and standards (https://www.gov.uk/guidance/monitoring-ambient-air-techniques-and-standards)

The index of monitoring methods provides guidance on the monitoring methods available for assessing levels of different pollutants in the ambient atmosphere. It should enable you to choose an appropriate monitoring method or technique.

Your ambient air quality monitoring and assessments must have proper
y assurance and quality control procedures
//www.gov.uk/guidance/monitoring-ambient-air-quality-control-and-
-assurance). You should have the necessary experience that shows
ompetence. Membership of a relevant professional body provides
onal assurance.

2. Reasons for conducting ambient air quality monitoring

You may need to do ambient air quality monitoring:

- as a requirement of a permit issued under the Environmental Permitting Regulations (EPR)

- for compliance with legislation requiring monitoring of the ambient atmosphere, for example the Air Quality Standards Regulations 2010
- by local authorities reviewing air quality in their area as part of the Local Air Quality Management system required under The Environment Act 1995
- as part of an Environmental Statement or a stand-alone air quality assessment submitted in support of a planning application (or to inform other spatial planning decisions) under relevant planning regulations
- as a post-development planning condition to provide a continuing check on any environmental effects and the effectiveness of any mitigation measures proposed
- for investigative or research purposes, such as investigation of health effects, atmospheric chemistry, or atmospheric pollution dispersion
- for monitoring the extent of leaks of gas products such as methane
- for monitoring of greenhouse gas emissions on a voluntary basis or as part of the requirements of carbon offsetting schemes

There may be more specific aims and objectives for carrying out an ambient air quality survey, and you may adopt a variety of sampling schemes for monitoring the pollutants. For example, the monitoring of traffic pollution may focus on roadside air sampling, whereas the monitoring of ozone pollution is often carried out at rural sites. A monitoring survey may consist of:

- a national network of air quality monitoring stations
- a smaller network designed to monitor regional or local air quality
- an assessment of air quality around a specific site or source

To make sure your sampling programme is technically valid and cost-effective, you should define the objectives of the proposed study at the n stage. The aims of different studies may vary but may include one re of the following:

- nparison of ambient air quality levels with standards, objectives, or ironmental Assessment Levels (EALs)
- establishing baseline levels before development of a new pollution source
- establishing baseline levels after commissioning of a new pollution source
- resolving the contribution of one plant or emission source from the background

- assessing the effectiveness of any abatement measures or control measures
- monitoring air pollutants crossing a site boundary
- monitoring nuisance effects, such as odour or dust
- responding to complaints
- verifying predicted ambient air quality levels, such as from modelling or chimney height calculations
- carrying out a survey using simple methods to decide if you need automatic monitors, and if so where you should be place them

3. The need for a monitoring strategy

You must design an air quality monitoring strategy so that it provides the most appropriate data to fulfil the aims and objectives of the survey. You must make decisions about:

- why do you need the monitoring
- what, where and when to sample
- how long to sample for
- how many samples to take and by what method
- quality assurance to make sure of appropriate results and to eliminate invalid data

Monitoring of common ambient pollutants is well established, with a range of automatic instrumental methods available, complemented by simpler manual methods. But the range of pollutants requiring measurement may be wide and may include many species where the measurement methods are not well developed.

urvey objectives and monitoring strategy

ata from a monitoring survey is normally used together with other igative tools (for example, modelling, observations, complaints, liance audits) to answer a particular question. For example:

- is the activity at the regulated site giving rise to nuisance impacts from dust at local residential dwellings?
- is the site activity giving rise to ambient particulate levels that exceed air quality standards?
- what is the flux (movement) of particulate matter across the perimeter of the regulated site?

These questions need different monitoring approaches. At a given site, more than one question may be relevant and so you may need several complementary monitoring approaches. This guidance describes how to design a monitoring strategy that aligns the monitoring survey with the aims and objectives of the study.

You must be clear on whether you want to measure the impact at receptors or the emission rate from the site boundary because they need different monitoring approaches. For example:

- if you want to quantify the impact at receptors, then monitor at the location of the receptors – if the question is one of human health impacts, then it is usually appropriate to measure the concentrations of the pollutant
- if the issue is one of dust nuisance impacts, then measurement of deposition rates using a horizontally orientated collection gauge will be relevant (for example, total mass dust deposition rate by a Frisbee gauge)
- most monitoring at receptors is omni-directional – you may need to also carry out directional monitoring if there are other significant local sources

If you want to quantify the emissions rate from the boundary of a regulated site, then you should monitor the rate at which the pollutant is crossing the site boundary at the perimeter of the site. For dust, the monitoring may be subjective observations of visual dust emissions or quantitative monitoring of dust flux using vertically orientated collection gauges.

What to consider when producing a monitoring strategy

What species to monitor

Once you have identified the target pollutant, you must decide in what [illegible] o monitor it. For example, total hydrocarbons or individual [illegible] ated) hydrocarbons, total particulate matter or a specific size [illegible] on.

[illegible] to sample and for how long

[illegible] ust decide if sampling should be continuous or intermittent. You must consider:

- the averaging period of the relevant air quality standard or objective with which you will compare the data
- whether the impact is acute or chronic
- the temporal resolution required (for example, short peaks averaged over 3 minutes, 1-hour averages, daily averages)

Short sampling campaigns are unlikely to give data representative of general conditions because meteorological conditions and source variations have significant effects on pollutant concentrations. Also, where short-term peaks are of interest, these may be unusual events occurring for only a few days each year. This means short-term monitoring campaigns are of limited value for characterising air pollution episodes, except for perimeter-fence monitoring of fugitive releases.

You must consider both the source and receptor when determining when to sample, for example:

- during the growing season for pollutant-affected crops
- during summer for photochemical episodes
- during high-wind-speed events for wind-raised dusts

How to sample

You must consider the type of sampling and associated analysis method. Sampling may be directional or omnidirectional – in-situ, mobile or open path. Method selection involves an appraisal of cost versus performance and goals. Performance includes:

- limits of detection
- sensitivity
- speed of instrument response
- susceptibility to interfering species
- accuracy of quantification method
- overall uncertainty of the measurement

Supplementary data collection

information may be relevant, for example meteorological tions, process data and traffic flows. Meteorological conditions are tant in assessing the impact of a source on its surroundings se they transport and disperse pollutants in ambient air. Many cal transformations between reactive species in the ambient air are also influenced by different conditions.

Where to sample

You must consider the location of sampling positions relative to the area of the study or the emission source. Examples are close to source for fence line monitoring, or distant or upwind for estimating background. Consider also individual sampling point criteria such as provision of essential services and absence from interfering sources.

Data handling and data analysis
You must consider if the time taken to generate results is important. For example, you may need results in real time for public health warnings, whereas several weeks may be adequate for supplying routine results for EPR permit compliance monitoring.

5. Existing monitoring data and supporting information

Before starting a monitoring survey, you should review other relevant monitoring programmes. Both national and local government, and several other organisations carry out routine monitoring programmes. You should consider these programmes at an early stage, to avoid unnecessary replication of data and provide a useful body of data to make comparisons.

You should also make a review of supporting information, such as regional or national emissions inventories providing information on source strengths and their geographical distribution. This could include supplementary data on population and traffic movements, if relevant.

National air quality monitoring networks are in place and are overseen by the Department for Food, Environment and Rural Affairs (Defra) and the devolved administrations. These automatic and non-automatic networks provide a valuable database on air quality levels within the UK. You can use them to support and supplement data obtained from local monitoring initiatives. Groups of local authorities run or sponsor other networks.

The Automatic Urban and Rural Network (AURN) has a summary of the techniques used for monitoring within the UK’ s national compliance monitoring network (https://uk-air.defra.gov.uk/networks/).

URN is the largest automatic monitoring network in the UK, ntly monitoring at over 100 locations across the UK (http://uk- ra.gov.uk/). They are at:

- or urban centres
- burban location
- rural locations
- remote locations
- roadside locations
- some industrial areas

The pollutants measured comprise nitrogen oxides (NOx), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), particulate matter (PM_{10} and $PM_{2.5}$).

The AURN collects data from each site every hour by telemetry. These data, along with archived data from current and defunct monitoring sites, are then made available on the UK Air website (http://uk-air.defra.gov.uk/). Also, Defra publishes annual reports, providing detailed descriptions of site locations and monitoring methods, with a summary of measured data against the relevant air quality standards and objectives.

The London Air Quality Network collates data from over 30 London borough councils to provide a detailed picture of air quality in London. This is in addition to the London AURN station. They archive and update data hourly on their website (http://www.londonair.org.uk).

Several non-automatic sampling networks supplement the automatic monitoring. These networks use simpler monitoring techniques such as diffusion tubes and often measure similar pollutants to those in the automatic networks, but at more sites. You can see the results on the UK Air website (http://uk-air.defra.gov.uk/).

Defra has set up the Air Quality Expert Group (AQEG) and the Committee on Medical Aspects of Air Pollution (COMEAP). They provide a forum for the review of current knowledge on air quality issues and its effects, and to provide recommendations to government.

Each of these review groups has prepared several detailed reports that summarise:

- air quality information
- monitoring techniques
- nds in pollutant concentrations
- cts upon human health and the environment

hich species to measure

This section identifies the types of pollutants you may need to measure.

6.1 Targeting the pollutant

For a single local source, emitting a mixture of non-reactive pollutants, the ambient monitoring of the concentration of one target pollutant may be enough to quantify the behaviour of others from the same source.

You must know the ratios of their relative abundance in the source emission. But this situation rarely occurs, which means it is usually necessary for you to consider ambient monitoring of several of the pollutants in the emitted mixture.

Usually, the target pollutants will be those strongly associated with the suspected emission source, for example:

- nitrogen oxides from road traffic
- fluoride from brickworks
- dust from a mineral extraction process

However, there are some instances where you must first identify the pollutant before you can quantify it (for example, investigation of nuisance odours). In the case of emissions from EPR permitted installations, the list of prescribed substances for release to air provides potential targets. You may need to prioritise the species emitted in the order of the ratios of their emissions concentrations (or expected ground-level concentrations if known) to their ambient air quality standards.

For many ambient air quality monitoring surveys, the aims and objectives will effectively define the pollutants that you need to measure. For example, monitoring for comparison with published air quality criteria or monitoring of the impact of releases under EPR. But, even when the pollutant species have been specified, you may still need to consider what form of the pollutant you should measure.

6.2 Different phases

Some pollutants exist in both gaseous and particulate phases. There are examples of both organic pollutants, (for example polyaromatic hydrocarbons – PAHs), and inorganic pollutants (such as mercury). The oring method needs to be able to sample the selected phase or hases, as appropriate.

tal and speciated measurements

For certain pollutants you may express the concentration as the total of the individual species present (such as total hydrocarbons). Alternatively, some members of a group of pollutants may be of special importance and may require specific determination (for example benzene, toluene, and xylene). You may also need to sample for a particular physical fraction, such as particles of diameter $\leqslant 10$ µm (PM_{10}) or diameter $\leqslant 2.5$ µm ($PM_{2.5}$).

6.4 Further chemical or physical characterisation

You may be able to identify pollutant sources by chemical analysis of the samples, because the presence, or ratios, of certain elements are characteristic to one of the sources. For example, you can characterise the $PM_{2.5}$ concentration of ambient air into the road-traffic derived fraction and that from wood-burners. This uses a dual wavelength aethalometer rather than a conventional particulate monitor. This quantifies the light-spectra peaks from analyses of the relative amounts of traffic particles to wood particles. Another example would be using the ratio of methane to carbon dioxide or ethane to characterise different greenhouse-gas-emitting sources and their combustion efficiencies.

You may be able to further characterise the whole sample or individual particles by scanning electron microscope (SEM) coupled with energy dispersive analysis by X-rays (EDAX). Physical characterisation by the visual appearance and morphology of particles under the optical microscope can also identify the source of the emissions.

7. Sample plan

Guidance on when to sample, how long to sample for, and how many samples to take.

7.1 General considerations

You must consider the duration of the whole sampling programme and whether you require continuous monitoring or intermittent sampling. You must also decide what the averaging period will be. You may also need to consider the requirements of air quality standards or objectives.

ill need to base your decisions on how you expect the pollutant ntration to vary with:

- e
- nature of the effects of the pollutant
- characteristics of the monitoring methods available

7.2 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. For example, most methods for precise quantification of gas fluxes (as opposed to threshold concentrations) are not possible to carry out on a continuous basis. You must continuously sample, if pollutant levels vary so frequently and significantly that intermittent sampling periods are not representative of the study period. You can carry out continuous sampling using automatic direct-reading real-time analysers or non-direct-reading manual sampling methods with longer sample averaging periods.

If you perform intermittent sampling, you must consider how long to sample for and how many samples to take. This links to the averaging period over which you report the measurements (see Section 7.3). If you are making measurements for comparison with an air quality standard, align with the averaging time of that standard. The duration of each sample should not be greater than the averaging period over which you expect to express it.

The duration of individual samples forming part of a continuous measurement may be smaller than the averaging time required for the results. This may be necessary because the measurement method has performance limits (such as sample saturation and sample breakthrough) or because the air quality standard is defined in this way. For example, an air quality standard may be an annual-average concentration calculated from daily (24-hour) samples.

You can find 2 approaches to scheduling intermittent sampling in the Handbook of Air Pollution Analysis by C.A. Pio (https://link.springer.com/book/10.1007/978-94-009-4083-3). The modified random system commonly used in air sampling networks, calls for sampling intervals of fixed length such as weekly. During this sampling interval, one day is randomly chosen for sampling. The other approach, called the systematic approach, requires the sampling programme to start on a day picked at random. Follow this by sampling at fixed intervals, other than 7 days, from that day onward.

he averaging period

ide choice of monitoring methods available accompanies a wide e of time periods used for measurements. The aims or objectives of study may in some circumstances define the averaging time. This is the case for monitoring to assess compliance with air quality standards and objectives. They specify the averaging time along with the limit concentration.

When the averaging period is not already fixed, you must decide it. Considering the expected short-term variability in pollutant concentrations and whether peaks are of importance. You must consider the receptor of concern and how long an exposure that receptor needs to experience possible harm.

Generally, you should measure pollutants that have acute health effects over short averaging periods. For example, sulfur dioxide has a major impact on receptor organisms over short-term high-concentration episodes. So, 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. So, there is a long averaging period that applies to the air quality standard for lead.

Some pollutants have more than one averaging time of interest because they adversely affect more than one type of receptor. 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.

The following gives some recommended averaging times for selected applications (Handbook of Air Pollution Analysis, D.J. Moore):

- 10 seconds for odour assessment, acute respiratory effects
- 3 minutes for odour assessments and acute respiratory effects if a faster response is not available
- 1 hour for dispersion studies, diurnal changes, discrete source studies, damage to plants
- 24 hours for chronic health effects, areas source studies, effects of weather systems, and effects on different days of the week
- 1 month for seasonal and annual variation, long-term effects from global source

oring ambient odour concentrations is a special case. Odours from
rial stack emissions are often noticed for only a few seconds at a
This happens when atmospheric turbulence causes the undulating
to reach ground level. You must collect ambient odour samples
hort averaging periods if you need to analyse these intermittent
.

The objective of the survey may be to verify or support predicted ground-level concentrations made by computer dispersion modelling. The predictions should themselves have been made using an appropriate averaging time. You must use the same averaging time in the monitoring survey.

The averaging period you chose may limit the choice of measuring techniques. This is because some methods may only operate within a fixed range of sampling averaging times. This is true for non-continuous manual techniques. because they have a laboratory analysis stage. This needs a sufficient mass of pollutant to achieve an adequate detection limit. The mass sampled depends on the pollutant flux to the sampler.

The determining factor is the sampling time, not only for diffusive sampling, but also for active sampling because the sampling flow rate is usually constant. You must consider the response time or sampling time of the method in relation to the required averaging period.

Often your choice will be between a direct-reading continuous technique providing a large quantity of data with a fine time resolution, and a less expensive, manual technique. You may use the manual technique to sample continuously, and this is adequate for many applications. An example is the widespread use of nitrogen dioxide diffusion tubes, which you usually expose for about two weeks. But application of an empirical factor to the results enables you to get an estimate of the 98th percentile of hourly means.

When logging data from continuous monitoring, the shorter the averaging period, the more data collected. An averaging period of one minute will produce 60 data points per hour, compared with 12 data points per hour if you log 5-minute averages. This means that you reach the data storage capacity of the logger over a much shorter monitoring period. It is also difficult to look at large datasets for example, a year’ s data in one-minute resolution. Some spreadsheet functions cannot cope with this volume of data.

7.4 Duration of the sampling programme

Pollutant concentrations are significantly affected by temporal variability, such as seasonal variations and diurnal cycles in rological conditions and emission patterns. There may also be day and weekend differences, and longer-term variations in, for ple, production, manufacturing, or fuel usage.

means that the data from a short-duration sampling programme be unrepresentative of the pollutant concentrations over time because it does not cover these variations. Short-term peaks may be unusual events occurring on only a few days in each year. If these episodes are of interest, then you may need to have an extended monitoring period to capture them.

A monitoring survey of a full year or more is required to take account of the full range of these variables. But 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. If you conduct intermittent sampling weekly, it is best to sample over a period of not less than 3 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 as discussed in [Urban Air Quality in the United Kingdom (https://archive.org/details/urbanairqualityi0000qual)](https://archive.org/details/urbanairqualityi0000qual).

8. Where to sample

The choice of monitoring locations for a survey is a compromise between competing considerations. The decision on where to sample links to the objectives of the monitoring survey.

8.1 General principles of sample location

If you need to quantify the impact, then ideally you should carry out the monitoring at receptors.

You may need to quantify the emission rate across the boundary of the regulated site (the pollutant flux) or check the effectiveness of pollution control measures. Any continuous monitoring should take place at least at the site perimeter if not further downwind. When conducting mobile measurements, carry them out downwind of the source at a great enough distance where emissions have mixed into a homogeneous plume. The sensor must retain the sensitivity to differentiate emissions from background level. This distance may range from several hundred metres to kilometres.

imate background levels, carry out monitoring upwind of the e or to the side of it. There should be no sources known to be d nearby.

hould consider the micro-scale siting criteria. This is the individual sampling point criteria (the micro-environment) that any location should meet to be suitable. For example, position relative to local emission sources and any interfering effects.

You should also consider the macro-scale location factors. This is the need to select representative locations for these sampling points relative to the study area or the emission source.

8.2 Micro-scale siting criteria – what makes a suitable monitoring point

Individual monitoring points must meet certain requirements to be suitable for measuring gaseous pollutants, airborne particulates or deposited dust around a site regulated by the Environment Agency.

You should make most measurements in an open setting with the sampler located away from large structures, such as buildings. This is to avoid the aerodynamic effects that they cause. Ideally, this distance should be equivalent to at least 5 building heights. subject to an absolute minimum distance from any building of 3m (but preferably at least 5m to 10m). An exception is if the aim of the study is to assess the impact at a sensitive receptor within this distance.

The following recommendations apply to active pollutant monitoring (that is using a pump to collect the air sample) at an individual location. Some of these recommendations are also relevant to passive monitoring (that is, where no pump is used), where you collect:

- a sample of gaseous pollutant on a sorbent by diffusion
- a dust sample by natural settlement or impingement from the air on to the collection surface

Sampling height

The concentration of a pollutant will vary considerably with height above ground, especially for emissions released from ground level. Here a difference of only 1m in monitoring height can result in noticeably different results. In most situations the height of the inlet drawing air into the monitor should be between 1.5m and 2m above ground level. This is a suitable height for assessing the impact on humans because this is the general height at which people breathe. If this is not possible to do, the height of the sample intake should be no higher than 8m ground level and preferably less than 4m.

ample intake probe itself should be unrestricted (free in an arc of at 70°) without any obstructions affecting the airflow in the diate area. The inlet sampling probe should normally be at least lear of the building or cabinet housing the monitor.

There are certain situations where you may need to monitor at a height greater than 2m above ground level. An example of this is where you need to remove the dominance of ground level emissions to assess the impact of elevated releases. This approach has been used on steelworks looking at the relative contributions to PM_{10} from fugitive emissions coming from the ground and process emissions coming from a high stack. By sampling at 20m above ground level, the data were dominated by the stack emissions. The approach effectively removed the influence of the fugitive, ground emissions. This example may be suitable for drone-mounted sensors if there is no need for continuous measurement.

Obstructions

Locate the sampling point, where possible, away from obstructions that will affect air flow. Buildings, walls, trees, and other obstructions can cause wind shadows and eddies that effect the distribution of pollution. Monitoring close to obstructions can mean that both the fluctuations of pollution and the overall average concentration will not be representative of the area. It is therefore preferable to monitor at a point that has an open an aspect as possible, allowing air movement with the minimum of disturbance.

Generally, the top of obstructions should subtend (that is when a line subtends an angle, lines drawn from its ends form that angle at the point where they meet) less than a 30-degree angle with the horizontal of the sampling point, This may be difficult to achieve in urban and suburban areas. It may be appropriate to monitor in an area affected by obstructions if the objective is to assess the impact at a particular sensitive receptor.

Overhang

Sampling points should be open to the sky, with no overhanging trees or structures. Trees can act as pollutant sinks. As a guide you can set 20m as the minimum distance from the dripline of trees.

Interfering sources

When monitoring to establish the impact from a specific source, the sampling point should not be subject to interfering influences or sources that are not related to the survey objective, such as:

- nearby rooftop vents
- chimney stacks
- ti-storey car parks

ed measurement sites, there should be no interfering sources of ion within 20m. The surrounding area (within 100m) should not be going major redevelopment. Do not leave vehicles running within the sample inlet.

Unless monitoring of pollution along roadways to the source of interest (for example a regulated site) is an objective, do not take samples within:

- 30m of a very busy road (greater than 30,000 vehicles per day)
- 20m of a busy road (greater than 10,000 to 30,000 vehicles per day)
- 10m of any other road (less than 10,000 vehicles per day)

When monitoring within rural areas the distances should preferably be greater.

For mobile measurements, you must take care to distinguish interfering sources by measuring either upwind or to the side of the source you are measuring.

Where you cannot meet these guideline criteria it may be necessary to use directional sampling apparatus. Alternatively collect concurrent meteorological data. This will enable the emissions from the source of interest to be clearly distinguished.

Topographical effects

You should not locate sampling points in areas where you expect unusual topographic effects, unless their investigation forms part of the aims and objectives of the study. Individual topographic features in an area may cause localised patterns of air flows, affecting the distribution of air pollutants over the area. For example, bringing the plume to the ground nearer to the source than you would otherwise expect. Topography may also have a large impact on measurements of wind speed and direction used in certain kinds of mobile measurement. The placement of anemometers must be relevant to concentration measurements and not in a wind shadow or on a point of unrepresentative prominence.

Access, security, and safety

Your sampling points must be accessible for servicing, calibration, and data collection. They should be secure and, in a location that minimises the risks of vandalism or accidental damage (for example by wildlife). You must also consider the safety of the public and monitoring operators.

Services

You must make sure the required services are available at the sampling points. Requirements vary according to the equipment, but could le:

- ctrical supplies for sampling equipment
- rnet connection for data collection
- conditioning for analyser

Other constraints

You may need to consider the desirability of co-locating sampling points for different pollutants.

You may also need to consider the visibility of the site in relation to its surroundings, and planning requirements.

8.3 Macro-scale factors for suitable location of monitoring point around regulated sites

Number of sampling points

Sampling involves obtaining data from a limited number of points in space and time. It is not practicable to obtain data continuously, from all possible affected locations. You must choose a limited number of sampling locations that are broadly representative of the general characteristics of the wider area.

As a general principle locate the sampling points so that you obtain the maximum amount of relevant information from the minimum number of monitoring locations. Assume that the pollutant concentration measured by the monitoring equipment:

- represents the concentration at the precise location of the sampler and
- is a good estimate of the typical concentration in the immediately surrounding area

The size of that surrounding area, and hence the number of monitoring stations required to adequately characterise the wider survey area, is dependent on the spatial variability of the pollutant in the area. You may assess this by computer dispersion modelling, but very often it is simply based on expert judgement. A short-duration preliminary survey or pilot survey may provide cost-effective information to optimise the design of the main survey.

The monitoring technique you use will also influence the number of monitoring positions that you can practically establish. For example, monitoring of NO_2 using passive diffusion-tube samplers is simple and cheap. You can potentially deploy them in greater numbers than a more costly and complex technique such as a chemiluminescence NO_2 ser.

ling points for monitoring exposure impacts or annoyance at ive human receptors

monitoring pollutant exposure impacts or dust annoyance, of a regulated industrial or waste management site, you should locate the sampling points at or very close to sensitive receptors. These are places where people spend lengthy and continuous periods of time, such as residential dwellings. They also include any places where the occupants may be especially sensitive to poor air quality such as schools or hospitals.

It is sometimes not practicable to monitor directly at or adjacent to the sensitive receptors and it is necessary to monitor at ‘proxy receptors`. These are other locations that are reasonably representative of the actual sensitive receptors.

If no other option is available, you may have to locate the sampling points inside the fence line of land under the control of the operator. This is usually much closer to the source than the receptor, so consider it a worst-case proxy receptor. If the relevant receptor-based benchmark limits are complied with at that location, then you can usually assume that they would be complied with at the (more distant) receptor itself.

Where there are many types of the same receptor nearby, for example a town, then monitoring is usually carried out at the nearest receptor to the regulated site.

An exception is when you carry out monitoring to quantify the exposure impacts of particulates from elevated point sources (for example stacks). Here the point of maximum impact will be some distance downwind, where the plume first intersects the ground. In such cases, atmospheric dispersion modelling may have been carried out as part of the environmental statement, planning application, or permit application. You can use the results as the basis for locating sampling stations where peak pollutant levels are expected.

Where there is only a single, isolated sensitive receptor local to the regulated site, pollutant measurements at a single sampling point may be acceptable. However, it is usually appropriate to have:

- at least one further sampling point to establish background levels in the area
- sufficient sampling points to allow upwind-downwind comparisons.

The following information outlines the key issues to consider when ing where to locate sampling points for monitoring impacts at ive human receptors.

nce from source

stance at which you position a monitor or sampler relative to the e of concern will have a significant effect on the concentrations measured. Pollution from a source will tend to disperse and dilute as it travels downwind. If the release is from a non-buoyant (ambient temperature) source at ground level, this dispersion will directly correspond to reduction in ground-level concentrations with distance from the release point. The degree of dispersion and dilution will depend on:

- the nature of the pollution

- the wind speed
- atmospheric mixing
- ground roughness
- other factors

When quantifying emissions using mobile methods it may be desirable to sample a well-mixed plume, which implies a typical distance from hundreds of metres to 1km from the source.

By contrast, a hot, buoyant plume (for example from a fire), or a plume emitted at some height above the ground (for example a stack emission), will take time to ground as it moves away from the release point. This means the point of maximum impact from this type of plume may be some distance away. It is sometimes convenient to approximate the maximum impact distance from a stack in terms of the effective height of the stack. This is the height to which the plume rises, considering plume velocity and buoyancy. Some estimates put the maximum concentration distance at 10 times the effective stack height, others at 15 or even 25. These are rough estimates and do not provide a precise prediction. You should also consider the physical characteristics of the pollutants. For example, larger particulate matter is subject to gravitational settling and may deposit closer to the emission source than gaseous pollutants.

A modelling study can be used to choose monitoring locations. A model can determine the point of maximum impact in terms of maximum hourly averages over the modelling period. Alternatively, it can determine the point of greatest average concentration over the modelling period.

Typically, you will use 1 to 10 years of meteorological data to determine the point of maximum impact. It is likely that if you chose a monitoring location that corresponded to this maximum prediction that the location l be too close to the stack. Only on rare occasions would the or measure releases coming from the stack.

etermine the point of greatest average concentration by averaging pact over a chosen time (for example, 5 years) at points over the lled area. The point of greatest average concentration will almost certainly be at a greater distance from the stack than the predicted maximum hourly average.

The maximum point is possibly the better monitoring location because the plume will impact here more frequently. The resultant measurements will provide more information about the nature of the source. This is particularly true if the monitoring study is over a relatively short period compared to the modelling period.

Multiple monitoring locations

When using more than one monitoring location to assess the impact from a source you must consider the location of the monitors or samplers with respect to each other. You can locate them at different bearings from the source and collect meteorological data concurrently with real-time data. The combined directional information can help you locate a point of emission. You can also gain information about the effect of distance from the source by locating them at the same bearing from a source but at different distances.

Prevailing wind

You must consider the prevailing wind conditions of the area when positioning monitors or samplers. In the UK, the predominant wind direction will generally be from between the south and the west. However, some areas may experience an unusual prevailing wind if the topography plays a significant role in directing the local air movement. An example of this is a valley where the wind tends to be directed up or down the valley.

Also, significantly altered air flows occur at the boundaries between water and air because of differences in temperature that can occur between the surfaces. When conducting mobile measurements, you should determine the instantaneous wind direction while measurements are being recorded. Then adjust the location to any changes that occur between measurements.

Upwind and downwind comparisons

You can assess the contribution from a specific source by placing 2 monitors in a line either side of the source (a transect). At the same time, you must collect representative meteorological measurements that you can collate with the pollution concentrations. Over a suitable time, subtract the average upwind concentrations from the downwind concentrations to determine the source contribution. When conducting mobile measurements, you may measure local background concentrations from the side of a source or its plume. You must be able ume that there is no upwind source near enough to cause ogeneity of concentrations into the upwind air flow.

ground conditions

sampling or monitoring surveys require data from one or more sites at background locations for comparative purposes. You should locate these away from the influence of major sources. They should be representative of the wider region. National or local authority monitoring networks may have sites that are suitable sources of background data.

Monitoring suspended particulate matter concentrations

You require a minimum of 2 sampling points, one upwind and one downwind of the site (in relation to the prevailing wind).

This allows you to carry out analysis of source contributions, particularly if wind speed and direction data are available. If you do not have local meteorological data available, you should consider installing wind speed and direction sensors at the site.

In some circumstances it can also be useful to have additional sampling points in the downwind direction from the site, along a transect. Data from these additional points are useful in assigning source contributions (as the contribution of site dust emissions will decrease with increasing distance from the site boundary).

Monitoring dust deposition or dust soiling rates

You require a minimum of 2 sampling points (upwind and downwind of the site, in relation to the prevailing wind).

It is useful, where applicable, to co-locate dust deposition gauges with suspended-particulate matter analysers.

It is useful to establish additional sampling points around the site to cover other wind directions and along a downwind transect.

Large numbers of monitoring points may be economic and practical for passive sampling of deposited dust but may not be so for more complex monitoring of suspended particulate matter (especially where you require further analysis, such as for heavy metals).

Sampling points for perimeter-fence monitoring of fugitive emissions across a site boundary

Fugitive emissions are often emitted relatively close to the ground level and are often monitored at fixed locations adjacent to the site boundary. This is known as perimeter-fence monitoring. Stationary open-path monitoring methods are well suited for this because they give a distance-averaged concentration over a long path length such as a boundary.

ve gas emissions often occur from air ventilation systems or tank
Gas plumes may also rise (or sink) because of buoyancy or local
spheric conditions. Mobile concentration measurements are well
to situations where the flux must be known accurately, with a
off of expense and short duration.

A common example of stationary perimeter fence monitoring is measurement of dust flux across a site perimeter of a regulated industrial or waste management site. Further information is provided in [Monitoring ambient air: particulate matter (https://www.gov.uk/guidance/monitoring-ambient-air-particulate-matter)](https://www.gov.uk/guidance/monitoring-ambient-air-particulate-matter).

Sampling points to measure pollutants against site-specific action levels and compliance limits

The Environment Agency may set site-specific action levels and compliance limits for dust, particulates, or gaseous air pollutants at industrial or waste management sites. Monitoring results exceeding these values would require actions to be taken to manage releases. Such action levels and compliance limits may be applied to impacts at receptors (for example dustfall monitoring) or to the rates of dust release across the site boundary (dust flux monitoring).

Sampling points to check that agreed mitigation measures are being effectively applied

Sampling points to check that agreed mitigation measures are being effectively applied may incorporate flux monitoring at the perimeter to show an agreed reduction in emissions released across the boundary. It can also be used to monitor exposure at sensitive receptors.

Ambient air pollution monitoring using continuous, automatic direct-reading instruments can provide virtually instantaneous quantitative evidence on the effectiveness of controls. However, for manual monitoring techniques the results are typically not known for several weeks after collection of the samplers. This means the results are of little benefit for providing immediate feedback on the effectiveness of improvements to pollution controls. But it can provide long term evidence of effectiveness.

For dust, visual inspections are a commonly used subjective technique for providing immediate feedback. You can combine this, where necessary, with real-time PM_{10} monitoring against short-term action levels.

Sampling points for monitoring exposure impacts at sensitive ecological receptors

Sampling points for monitoring exposure at sensitive ecological receptors will depend on where the sensitive ecological sites are in relation to regulated sites. For sites that release pollutants from elevated point sources (for example stacks), atmospheric dispersion modelling s can identify the areas of impact.

ine monitoring and background monitoring points

are monitoring to quantify the impacts of a regulated industrial or management site on receptors, you will usually need to understand:

- how much of the pollutant is from the site (the process contribution, PC)
- how much is from the general background and other sources in the area (the background contribution, BC)

For proposed developments not yet in operation, it is possible to carry out a period of baseline monitoring on the development site, or close to it. It must be in an area representative of where people are to be located (assuming monitoring is to quantify nuisance or human health impacts). The monitoring surveys should ideally be for one year, although 6 months of data spanning both the winter and summer may be adequate. Surveys of less than 3 months duration are unlikely to provide sufficiently representative data.

Baseline monitoring is not possible at sites already in operation. Instead, you can use a background monitoring location to provide control samples that show the underlying background pollution levels. Ideally, this will be at a point that is:

- predominantly upwind of the site
- far enough away so that the sampler is not significantly influenced by pollution from the site
- where the normal daily background influences for the area can be expected

The zone of influence will vary from one regulated industrial or waste management site to another. It will depend upon factors such as the source emission strength, prevailing wind direction and terrain.

Former planning guidance (Minerals Policy Statement 2) (https://cumbria.gov.uk/elibrary/Content/Internet/538/755/1929/17716/17720/17723/42130142312.PDF) for surface minerals sites stated “residents can potentially be affected by dust up to 1km from the source, although concerns about dust are most likely to be experienced near to dust sources, generally within 100m, depending on site characteristics and in the absence of appropriate mitigation” . For construction and demolition sites the IAQM guidance (https://iaqm.co.uk/text/guidance/guidance_monitoring_dust_2018.pdf) has set a default cut-off distance for dust effects of 350m.

m is not to select a background location that is separate from all ble and potential sources of pollutant that people may be exposed part of their normal daily life. The normal background for an area ry at different places and times. For example, some receptors may experience higher background pollution from roads, whilst others may experience higher background pollution from agricultural activities. For this reason, any review of the suitability of a potential background location needs to take a view on whether there are major factors that make it unsuitable for characterising the background of the wider area, whilst noting that there will be differences between the chosen location and any individual receptor.

Sometimes it is not practicable to install monitoring equipment at an off-site location, due to a lack of security, power connection, and access. In these instances, you may need to place the sampling points on land within the site operator’ s control. In such cases, at least one of the samplers should be in the predominantly upwind direction of the site activities. This enables upwind-downwind comparisons of results to be made. Upwind sampling points close to the site will not give true background results. They may be predominantly upwind but will still receive winds from the on-site sources for some of the time.

9. Accompanying measurements and supplementary data

It is important to collect other types of information that may influence the monitoring results.

9.1 Meteorological data

Meteorological factors are important because they:

- determine the transport and dilution of pollutants in the atmosphere
- influence chemical transformations of species in the air
- affect the mechanisms and rates of removal of pollutants from the atmosphere

You should assess and possibly measure meteorological conditions and emission source details. Diurnal and seasonal variations in meteorological conditions can superimpose effects on top of those caused by variations in the pollutant emission source strength.

Also, if the aim of the monitoring study is to attribute pollution episodes to individual regulated sources, then knowledge of wind direction and speed is essential (unless you use directional samplers).

applying mobile quantification methods, it is also essential to ure a representative wind speed and direction for mass-balance olation. This is less important for tracer gas comparisons. If you use drone-mounted sensors, you should account for changes in wind speed and direction with height in the atmosphere.

Emissions from sources are diluted and transported within a relatively shallow boundary layer adjacent to the Earth’ s surface, typically no higher than 100m to 1300m. Within this layer, turbulence causes progressive dilution of the pollutants with cleaner air as the wind transports the pollutants away from the source. The roughness of the terrain, the strength of the wind and rising parcels of warmer air create this turbulence.

Here is an outline of the meteorological parameters that you must consider in an air quality monitoring strategy.

Wind speed and direction
These are often measured at one or more of the monitoring sites to indicate which direction the sampled air comes from. Ambient pollution levels are often inversely proportional to wind speed.

Temperature and solar radiation
Measured less often but can be useful for:

- estimating the likely atmospheric stability conditions
- interpreting measurements of photochemically reactive chemicals such as ozone
- assessing the generation of secondary pollutants, such as nitrogen dioxide

The Met Office can provide information on atmospheric stabilities and mixing heights.

Rainfall, mist, cloud, humidity, and surface wetness
These provide information on the mechanisms for removal of atmospheric pollutants and are particularly important for studies of the corrosive effects of air pollutants on materials.

These parameters are also important for interpreting the results of dust surveys. Dryness and low humidity can result in increased suspended particulate concentrations because of suspension of surface dust. You can also use cloud cover to infer solar radiation.

Measurement of meteorological parameters takes place at many
ons across the UK by the Met Office and some other organisations.
ne situations, you can make use of these data. In others, the highly
sed nature of meteorological conditions makes it necessary to
out measurements of meteorological conditions at the point of
ing.

9.2 Other information

Information on the source of pollution is important. Some industrial processes may be cyclic, over periods of hours or days. Others may shut down overnight or during certain times of the year. Interpretation of ambient data can be helped by having information on activity patterns and fuelling practices, for example:

- position on growth curve of intensively farmed poultry
- details of fuel-switching at power stations

In some cases, it may be necessary to take account of time lags between changes at a source and changes at an ambient monitor, due to the time required for dispersion through the atmosphere from source to monitor.

This information can be especially important when conducting ’ snapshot’ emissions quantification created from mobile concentration measurements. You should repeat measurements as often through the year as practicable and take account of any expected variability in conditions of sites when measuring. For example, on landfills, it is important to consider the impact of atmospheric pressure.

The daily pattern of local traffic flow will be important in interpreting data if monitoring traffic pollution is the specific aim. It may also be important for other monitoring surveys if the monitoring position means measurements are subject to interference from busy roads.

10. Data handling

How you acquire data from the monitoring site depends on the type of equipment involved and the type of survey being undertaken. Many of the indirect monitoring techniques have an analytical end-method stage that is separate from the sampling stage. In such cases some of the data will come from the on-site sampling (for example flowrate, volume) but the analytical results will come from a laboratory.

In contrast, direct-reading continuous analysers provide data stored on-site using automatic data-loggers and, increasingly, connected by a webserver to a host website for data access and processing. Most instruments and data-loggers will sample the measured output at frequent intervals and then compress this data into more manageable averaged periods. You can specify both the sampling interval and eraging time. You must make sure you choose times that are priate to the:

- age capacity of the logger or host website
- ponse time of the instrument
- temporal variability in pollutant concentrations
- regulatory requirements

Web-enabled systems allow for virtually real-time presentation of the results which you may still need to inspect to make sure of their validity. They perform some instrument performance-checks and diagnostics to check for correct operation. Some may allow initiation of instrument span and zero checks. Web-enabled transmission of instrument data is especially important when there are many sites in a network, or where a site is not easily accessible.

11. Analysis of results and reporting

The following section describes how to analyse and report the results of your monitoring campaign.

11.1 Presenting the raw data

Analysing collected data is an essential part of ambient air monitoring. The following are examples of questions that you should answer by analysing data:

- are prevailing ambient air pollution levels acceptable?
- where is the pollution coming from?
- what are the overall trends (are things improving)?
- what conditions give rise to elevated levels of pollution?
- what activities give rise to elevated levels of pollution?
- is mitigation working?
- what is the impact of a specific plant?
- does the data verify predicted levels?
- can you use the data to estimate source emission rates?
- can you reconcile whole-site emissions rates (top-down measurements) with aggregated unit-level measurements (bottom-up measurements)?

ssessment against air quality standards

f the main reasons for doing ambient monitoring is to establish er the air at the monitoring point is compliant with air quality ards. The following are types of air quality standard:

- short term – where a pollutant must not exceed a set concentration limit on more than the specified number of occasions during a year
- long term – where a pollutant must not exceed an annual average

Short-term or long-term standards reflect the nature of the pollutant and whether its effect on human health or other receptors is acute or chronic.

Continuous monitoring data are usually collected as either 15-minute or hourly-averaged readings. However, many of the standards require data conversion to different averaging periods before comparison. For example, SO_2 has standards for 15-minute, hourly and 24-hour (midnight to midnight) averaged data, while the standard for CO is an 8-hour rolling average. Rolling averages or moving averages tend to smooth out short term fluctuations and highlight longer term trends and cycles. Each new data point must be the average of at least 75% data (for example, at least three 15-minute averages to make up an hourly average).

Once you have converted the data to the required resolution, you can determine the number of exceedances of a particular standard. Where the benchmark period is a year, but the monitoring period is shorter than a year, you must extrapolate the data to estimate the number of exceedances that would have occurred over a year. For monitoring periods shorter than the benchmark year, you must consider how representative the period was in terms of:

- wind direction
- source activity
- rainfall
- season

For example, you would expect monitoring around a waste transfer site to show a greater number of PM_{10} exceedances in dry summer months than during wetter winter months. You should use caution when the number of exceedances of a standard are only just within the permitted allowance. Under different meteorological conditions that standard may be exceeded. Such situations may warrant further monitoring.

11.3 Source apportionment

n use several different types of analysis to extract information he monitoring data. They include directional, temporal and rrence analysis techniques. These techniques described in oring ambient air: data analysis techniques //www.gov.uk/guidance/monitoring-ambient-air-data-analysis-techniques).

11.4 Air quality data analysis software

Openair is a software package for analysing air quality data. Openair uses a programming language called ‘R’ , a freeware version of the commercially available S-Plus statistical programming language. See Openair: open-source tools for analysing air pollution data.

11.5 Report content and structure

You should usually include the following in an air quality report:

- non-technical summary
- statement of aims and objectives
- description of the strategy adopted to fulfil the aims and objectives
- a statement on the standard published method, or in-house documented technical procedure used
- a summary of the technique and methodology used for both sampling and analysis
- a statement of who carried out the work and by which organisation
- the equipment type, make, and models used
- details of the monitoring points on a map
- a summary of the quality assurance and quality control systems in place
- a summary of measurement results (expressed in the correct units)
- a statement of uncertainty on the results
- a statement on the traceability of the results
- a statement as to whether the tests complied with the test method procedural requirements
- a summary of any changes to the test method procedure
- observations relevant to the sampling period (for example weather conditions)
- mparison with the air quality standards or EALs that apply
- cussion on relevant factors affecting results for this period
- ether there has been compliance with the environmental quality ndard
- a statement on what the longer-term trend is, if any, based on the reported results
- recommendations, if relevant
- appendices containing raw data, sampling records, worksheets used, analysis certificates, and further details of methods used

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