REPORT

A Guide for Local Authorities Purchasing Air Quality Monitoring Equipment

A report produced for the Department for Environment, Food and Rural Affairs, the Scottish Executive, the Welsh Assembly Government and the Department of the Environment in Northern Ireland

AEAT/ENV/R/2088 Issue 2
August 2006

A Guide for Local Authorities Purchasing Air Quality Monitoring Equipment

A report produced for the Department for Environment, Food and Rural Affairs, the Scottish Executive, the Welsh Assembly Government and the Department of the Environment in Northern Ireland

AEAT/ENV/R/2088 Issue 2
August 2006

Title	A Guide for Local Authorities Purchasing Air Quality Monitoring Equipment.
Customer	Department for Environment Food and Rural Affairs, the Scottish Executive, the Welsh Assembly Government and the Department of the Environment in Northern Ireland
Customer reference	CPEA 8
Confidentiality, copyright and reproduction	Copyright AEA Technology plc. All rights reserved. Enquiries about copyright and reproduction should be addressed to the Commercial Manager, AEA Technology plc.
File reference	ED45098
Report number	AEAT/ENV/R/2088
Report status	Issue 2

Diane Mooney
AEA Technology plc
Netcen
Building 551.11
Harwell
Didcot
Oxfordshire
OX11 0QJ
UK
+44 (0) 870 190 6536 tel.
+44 (0) 870 190 6377 fax.

diane.mooney@aeat.co.uk

Netcen is an operating division of AEA Technology plc
AEA Technology is certificated to BS EN ISO9001:(1994)

	Name	Signature	Date
Author	Diane Mooney		
Reviewed by	Paul Willis		
Approved by	Ken Stevenson		

Executive Summary

Under the Environment Act 1995 and subsequent regulations, local authorities are required to review and assess the air quality in their area. This assessment may require air quality monitoring to be carried out. In some circumstances indicative monitoring may be sufficient, but in other cases (refer to TG LAQM.TG (03) for guidance) more accurate and reliable detailed monitoring will be required. In this case, it is recommended that local authorities use equipment similar to that deployed in the National Monitoring Networks and adopt equivalent operational procedures.

The aim of this document is to provide a simple guide and check list for local authorities wishing to purchase and operate automatic air pollution monitoring equipment for detailed monitoring.

It is intended to be read in conjunction with:

- Defra's Technical Guidance for Review and Assessment LAQM TG (03)
- The AURN Site Operator's Manual http://www.aeat.co.uk/netcen/airqual/reports/lsoman/lsoman.html, and,
- The Frequently Asked Questions (FAQ's) on the LAQM Helpline page of the Air Quality Archive at http://www.airquality.co.uk/archive/laqm/helpline.php

For further information, contact the Local Authority Air Quality Support Helpdesk at 0870 190 6050 or lasupport@aeat.co.uk

Contents

1 Introduction

Any air quality-monitoring programme is likely to involve a significant investment of resources and this needs be recognised at the outset. The correct selection of equipment and operational procedures is essential to ensure that these resources are not wasted and that the results obtained fulfil the original requirements for the monitoring exercise.

A key specification will be to obtain data over the correct time averaging period for comparison with the Air Quality Objectives. For example, for SO_2 and for NO_2 15 minute and hourly data are required, respectively.

The current Air Quality Objectives set by the Government and Devolved Administrations are listed below:

Pollutant	Air Quality Standards
Carbon Monoxide (CO)	England, Wales and Northern Ireland • Maximum Daily running 8-hour mean 10μgm^{-3} Scotland • Running 8-hour mean 10μgm^{-3}
Oxides of Nitrogen (NO_x)	• 1-hour mean 200μgm^{-3} (not to exceed 18 times per year) • Annual Mean 40μgm^{-3}
Sulphur Dioxide (SO_2)	• 1-hour mean 350μgm^{-3} (not to exceed more than 24 times per year) • 24-hour mean 125μgm^{-3} (not to exceed more than 3 times per year) • 15-min mean 266μgm^{-3} (not to exceed more than 35 times per year)
Particulate Matter (PM_{10})	England, Wales and Northern Ireland • 24-hour mean 50μgm^{-3} (not to exceed more than 35 times per year) • Annual Mean 40μgm^{-3} Scotland • 24-hour mean 50μgm^{-3} (not to exceed more than 7 times per year) • Annual Mean 18μgm^{-3}
Benzene	England, Scotland, Wales and Northern Ireland • Running annual mean 16.25μgm^{-3} England and Wales • Annual mean 5.00μgm^{-3} Scotland and Northern Ireland • Running annual mean 3.25μgm^{-3}
1,3-butadiene	• Running annual mean 2.25μgm^{-3}
Lead	• Annual mean 0.5μgm^{-3} • Annual mean 0.25μgm^{-3}
Ozone (O_3) (Not required for Review & Assessment)	• Running 8 hour mean 100 $\mu g/m^3$ (Daily maximum of running 8 hr mean not to be exceeded more than 10 times per year)

2 Air Quality Monitoring for Review and Assessment

As noted previously, undertaking air quality monitoring can be a significant commitment, both in terms of capital expenditure and staff time. It is therefore essential that detailed planning of the programme be undertaken prior to commencement. The following questions should be considered before proceeding with any air quality monitoring project:

- What pollutants need to be monitored?
- What monitoring methods are appropriate?
- What else is needed for the installation?
- What level of QA/QC is required?
- Where is it practical to locate the equipment?
- How long to monitor for?
- Will "accredited" calibrations help?
- How much will all this cost – to purchase, to operate and to maintain?

Even if the local authority decides to contract out all or part of the project to a consultant, they should still make sure that all these questions are addressed in the project specification.

In the following sections we provide some basic advice on how to answer these questions. For further help please contact the Local Authority Air Quality Support Helpdesk at 0870 190 6050 or lasupport@aeat.co.uk

2.1 MONITORING EQUIPMENT

Netcen has prepared a general list of suppliers of all air monitoring equipment.
This is available at http://www.airquality.co.uk/archive/reports/cat06/aqm_suppliers.pdf

In general, the instruments in the National Monitoring Networks use the measurement methods prescribed in EU Directives.

Equipment suppliers should be able to demonstrate that their analysers are "fit-for-purpose", and have some form of independent evaluation e.g. the ambient MCERTS scheme operated by SIRA, the United States Environmental Protection Agency (USEPA) Federal Register or German TUV designation. It is recommended that analyser performance conform to EU Directive requirements as specified in BS EN 14211 (NO_x), BS EN 14212 (SO_2), BS EN 14625 (O_3) and BS EN 14626 (CO). For PM_{10} monitors it is recommended when purchasing new instruments, or replacing existing equipment, that they meet the equivalence criteria as described within the recent "UK Particulate Monitoring Equipment Study".
http://www.airquality.co.uk/archive/reports/cat05/0606130952_UKPMEquivalence.pdf
Also, analysers will need to be able to monitor over the time period of the air quality objective – e.g. 15-minute for SO_2.

A brief summary of approved monitoring methods is provided here for information.

More details of the principle of operation of the analysers and detailed procedures for calibration and operation of these analysers is provided in the Site Operator's Manual for the AURN which is available as a research report at
http://www.aeat.co.uk/netcen/airqual/reports/lsoman/lsoman.html

Carbon Monoxide

In the national network, gas filter correlation infra-red absorption analysers are used for monitoring carbon monoxide.

There are a number of portable electro-chemical analysers available. However these are generally of low sensitivity and are not suitable for ambient monitoring. They are only recommended for screening studies. Remote optical and long path analysers are discussed below.

Oxides of Nitrogen

In the National Network, chemiluminescent analysers are used for continuous nitrogen dioxide monitoring.

There are also a number of portable electro-chemical analysers, however, they are generally of low sensitivity and accuracy; they are not suitable for detailed ambient monitoring and only recommended for screening studies. Remote optical and long path analysers can also be used and are discussed separately below.

For local authorities who need to monitor at locations where NO_x and NO concentrations fluctuate rapidly, for example at kerbside or roadside sites, there are enhanced instruments that avoid producing negative NO_2 data by using dual chamber systems, increased cycle frequency and/or delay loops.

Sulphur Dioxide

In the National Network, UV fluorescent analysers are used for continuous sulphur dioxide monitoring.

As for monitoring for oxides of nitrogen, there are also a number of portable electro-chemical analysers. Remote optical and long-path analysers can also be used and are discussed separately below.

Particulate Matter

PM_{10} particles can be monitored by a range of analyzer types, potentially giving very different results.

Defra and the devolved administrations have undertaken a study on the equivalence of various samplers and instruments for measuring particulate matter, in comparison with the European standard method. For further information, please refer to the "UK Particulate Monitoring Equipment Study" report at http://www.airquality.co.uk/archive/reports/cat05/0606130952_UKPMEquivalence.pdf

The outcome of this study means that the National Network will have to be restructured with instruments that meet the equivalence criteria and compliant with the Directive. As yet, this has not been decided but the TEOM analysers in the network will either need to be replaced or upgraded. Local Authorities are encouraged to use instruments that meet the equivalence criteria wherever practicable (and should certainly consider their use in any procurement programmes), but Defra and the DAs consider that the TEOM analyser (with appropriate correction factor) remains suitable for use as part of the LAQM programme. The particulate monitoring methods available are:

- Filter Dynamics Measurement System (FDMS). The FDMS is a self-referencing airborne particulate monitor based on TEOM technology measuring core and volatile fractions of particulates. This equipment met the equivalence criteria of the above study and is suitable for use.
- TEOM (Tapered Element Oscillating Microbalance). The outcome of the study meant that the TEOM did not meet the equivalence criteria of the European reference method within the UK, even with the 1.3 correction factor. To meet the equivalence criteria, it may be possible to upgrade the TEOM analyser, depending on the model, to an FDMS by a simple retrofit.
- Beta Attenuation Mass Analyser. These are available with heated and non-heated sample inlets. As part of the study, the un-heated Met-One Bata Attenuation Monitor (BAM) was tested and met the equivalence criteria with a correction factor for the slope i.e. to divide by a factor of 1.2. For analysers with heated inlets used for LAQM purposes, the advice is to continue to multiply by a factor of 1.3 to estimate gravimetric equivalence.

- Gravimetric samplers. Sequential gravimetric instruments (Partisol 2025) are used at some sites in the National Network. These have 16 filters to allow operation over a two-week period. The instruments were tested in the equivalence programme in this mode of operation, and were found to be equivalent, with stringent QA/QC applied If single measurements are made then samples should be exposed daily if possible or at least every alternate day (including weekend days). Filters should be weighed and conditioned. (see QA/QC section below)

For further advice on the selection of monitors, please refer to the following FAQs

- UK Equivalence Tests for Particulate Monitors http://www.laqmsupport.org.uk/faqs.php?action=showpost&question_id=1377)
- Equipment Upgrade (http://www.laqmsupport.org.uk/faqs.php?action=showpost&question_id=1378)

Light scattering systems are available for particle monitoring but these are only advisable for screening studies and not recommended for Detailed Assessments

Benzene and 1,3-butadiene

Two techniques are used in the national networks for monitoring of benzene and 1,3-butadiene. The automatic monitoring techniques for these species are based on continuous automatic gas chromatography (GC) systems, which measure benzene, toluene, ethyl-benzene and Xylene isomers as well as 1,3-butadiene and, in some cases other species. Pumped tube systems are also used for benzene monitoring. A very low volume of air is drawn through the tubes over a 2-week period. The tubes are then sent for analysis, by GC, at a suitable laboratory.

Diffusion tube samplers can be used as an indicative monitoring technique for benzene.

Lead

Lead is monitored by collecting samples onto a filter using a suitable sampler. In the national network monitoring at all sites is now conducted on a weekly basis, using samplers equipped with PM10 size selective inlets, and subsequent extraction and analysis conducted using techniques consistent with the CEN WG14 proposed reference method.

Other samplers commonly used are the 'M Type' sampler with analysis by atomic absorption spectroscopy or inductively coupled plasma mass spectrometry. Samplers with PM10 inlets can be used for lead sampling for the Air Quality Strategy objective.

Ozone

In the National Network, UV absorption analysers are used for continuous ozone monitoring. However, the objective for ozone is not included in the current air quality regulations nor is it required for the Review and Assessment Process.

Remote optical/long-path monitoring

Differential Optical Absorption Spectrometry (DOAS) systems are available in the market for monitoring ambient air quality. This equipment is useful for source monitoring although the data may not be readily comparable with point measurements. As with all types of monitoring equipment, a high standard of maintenance, calibration, operation and quality assurance and quality control procedures is required to obtain reliable data.

The MCERTS certificate on such type of remote sensing equipment, advises, " The maximum path length for consistence with a point analyser is indicative only and will depend on the mode of application. Longer lengths can be expected at well-mixed background locations, whereas in street canyons greater non-homogeneity of concentrations will occur. For this reason site specific investigations are recommended for each application if the results are to be interpreted in terms of Air Quality Guidelines"

2.2 PURCHASING CHECK-LIST

When purchasing equipment to set up a monitoring station there are a number of other important items to specify in addition to the type of monitoring equipment to be used. A menu is provided below which we recommend should be used as a tick-list during the procurement process:

Tick

- **Monitoring site enclosure**

If the equipment is going to be self-contained rather than in an existing building then an enclosure will need to be purchased. Consideration needs to be given to the size, portability, and visual impact requirements of the enclosure. These criteria will need to satisfy the needs of the particular location, or overall programme if the site is to be frequently re-located.

- **Air conditioning/heating system**

In most cases if budget allows it is advisable to install monitoring equipment in an air-conditioned enclosure/room. Exceptions are if only one or two monitors are to be installed in a large enclosure, or if a room is particularly well insulated and ventilated. In general the problem is with over-heating of equipment in the summer so a cooling system is required. However, there may also be instances where the instruments themselves do not generate sufficient heat to warm the surroundings so a heating system may also be needed for winter months. Some monitors such as the infra-red absorption analyser for carbon monoxide can be particularly susceptible to temperature change, leading to a risk of expensive instrument failure or severe data loss if not protected.

- **Sampling inlet**

Different sampling systems can be purchased depending on the amount of equipment to be installed and the location. There are two main types of sampling systems used in UK monitoring stations:
- Those that use the analyser to draw air through a narrow fluorocarbon tube which is passed through the monitoring enclosure to the ambient air. Typically this system is used where there are only one or two analysers at a site.
- Those that use a fan to draw ambient air at high speed down a wide manifold tube. The analysers are connected to the end of this manifold using short lengths of narrow fluorocarbon tubing, and this type of system is best suited to multi-pollutant sites.

- **Power supply**

The power supply to the monitoring enclosure/room needs to be of sufficient rating to support the amount of equipment to be installed. A suitable trip is usually installed in order to prevent accidental damage to the equipment in the event of a power surge.
In some cases such as roadside monitoring it is possible to organise drawing power from a nearby facility such as street lighting without having to install significant lengths of underground or over-ground cables. However, not all such installations offer a 24-7 power supply.

- **Telephone connection** **Tick**

In order to ensure that analysers are operating satisfactorily, data should be downloaded remotely from monitoring stations on a daily basis. If a real-time public information system has been set up then data polling may be increased to every hour. In order to achieve this installation of a telephone line and MODEM, or mobile phone and GSM MODEM will be required. The type of system required will depend on location, cost of installation, and ongoing cost of calls and monthly rental. Some modern analysers can be connected directly to a broadband line with data then collected over the Internet.

- **Meteorological sensors**

In order to make the best use of the measured air quality monitoring data for dispersion modelling or source apportionment analysis, it is often useful to install meteorological sensors at the monitoring station. These will enable the local wind speed/direction/temperature/humidity data to be analysed to determine the conditions which lead to high pollution, and which are the most significant pollutant sources. Consideration will need to be given to the visual impact of installing a meteorological mast and whether overhanging or nearby buildings or vegetation might interfere with the sensors. Meteorological measurements are usually going to be most effective when the monitoring station is in a reasonably open location. The alternative is to purchase sequential meteorological data from the Met Office, but this may only be modelled or from a monitoring station many miles away.

- **Data logging**

Most automatic air quality monitors now have their own sophisticated controlling software and built-in data loggers which can store up to a month or more of 15-minute averaged data. If more than one analyser is to be installed then a code-activated-switch will be needed in order to allow remote polling to download data from each of the analysers in turn. An alternative is to install a dedicated PC or data logger at the site to store all the data and control operation of the analysers including calibration cycles. Consideration will also need to be given as to whether additional parameters such as meteorology and analyser status need to be recorded, where these values will be stored, and how they will be downloaded.

- **Calibration systems**

Automatic daily calibration systems can be installed to provide checks of instrument response to zero air and calibration gas. This will enable rapid identification of instrument malfunction or drift, and help to maximise data capture.
In addition, site operators will still ideally visit the monitoring location every couple of weeks to visually inspect and check the site operation. Whilst at the site the operator needs to have the facility to carry out a manual zero/span check of the gas analysers with a zero source and cylinder of accredited gas standard. If automatic systems are not available **it is essential** that a facility to perform manual calibrations every fortnight be installed. Without regular calibrations of this kind the monitoring data will be useless.

- **Service and maintenance contract**

Tick

☐

Automatic air quality analysers are sophisticated and will require engineer support for repair and routine maintenance. Ideally when purchasing analysers a contract should be set up to replace or repair any faulty equipment within 48 hours of call-out, ensure a minimum data capture level of 90% over the year or monitoring period, and to carry out routine servicing of the equipment every six months according to the manufacturers recommendation. It will be up to the operator to decide whether to take up an expensive "all-inclusive" maintenance contract covering all eventualities, or to go for the cheaper but more risky option where individual possibly expensive items will have to be paid for in the event of breakdown.

Maintenance schedules for the replacement of consumable parts, diagnostic checks and equipment overhaul should in all cases follow manufacturer's recommendations. Routine and non-routine service visits must be fully documented to describe in detail any adjustments, modification or repairs undertaken. The exact service schedule and level of documentation should be agreed as part of the service contract.

A good service and maintenance contract on a well set-up, calibrated and maintained site should ideally ensure that any data loss is distributed evenly throughout the year. An example "model" contract (as used in the National monitoring network is provided in the Site Operator's Manual of the AURN (Appendix F) which is available as a research report on
http://www.aeat.co.uk/netcen/airqual/reports/lsoman/lsoman.html

- **Data management**

☐

Data from the monitoring stations needs to be reviewed on a daily basis in order to:

- Ensure that the equipment is still running satisfactorily.
- Provide information on pollution alerts to the public.
- Backfill any data gaps if necessary.

All or part of this service could be sub-contracted to a specialist consultant, with data linked in real-time to a web site for public information. However, if the local authority decides to carry out the task themselves then they will need to purchase the necessary software for:

- Data download, functional review, editing and comparison with Air Quality Standards.
- Reporting and upload to a web site if required.

Most suppliers of air quality monitoring equipment will be able to provide software to the local authority for this purpose.

- **Quality assurance and control**

Tick

☐

A documented quality assurance and control programme must be followed in order to ensure reliable and credible measurements. Typical QA/QC programmes include an established schedule of regular site calibrations, validation and ratification of data, independent site audits, and documentation of all procedures. Again, the local authority may wish to contract out some or all of these functions to an independent consultant. Typically it is the data ratification and site audit functions which are best carried out independently, with routine site visits being the responsibility of the local authority themselves.

The overall uncertainty of any given measurement is calculated from a summation of individual uncertainties for the monitoring method. For an automatic monitoring method these would include:

- Precision of the analyser.
- Linearity errors of the analyser.
- Uncertainty of the gas standards.
- Stability of the output signal.

In order to minimise measurement uncertainty it is important to apply stringent QA/QC procedures to the monitoring programme – such as those used in the national networks. Independent site audits should provide accredited measurements of the uncertainties above, together with:

- Scaling factors for each of the analysers.
- Checks of NO_x converter efficiency.
- Interference and leak testing of analysers.
- Testing and reporting of flow rates against specified operating parameters.

Data ratification is a periodic (usually quarterly or bi-annual) review of the monitoring data which will examine the results to:

- Apply the most appropriate zero and sensitivity factors based on the instruments' calibration history, and to avoid reporting any negative concentrations.
- Remove any spurious or faulty data.
- Make any adjustments to the data based on the results of the QA/QC audits.

QA/QC procedures used in the National Monitoring Network are outlined in the Site Operator's Manual of the AURN (http://www.aeat.co.uk/netcen/airqual/reports/lsoman/lsoman.html)

For PM_{10} gravimetric samplers, it is important that the filters used are properly conditioned and weighed in a controlled environment before and after exposure. Weighing must be carried out using an accurate calibrated balance. Filter handling and weighing should conform to a recognized standard such as **EN12341**. A recent study conducted by the National Physical Laboratory for Defra and the DAs gives useful advice on the selection of appropriate filters for gravimetric samplers and detailed procedures for handling, transporting, conditioning and weighing filters. Note the Partisol 2025 has only shown to be an equivalent method when using the stringent QA procedures described in this report. The NPL report can be found at http://www.npl.co.uk/environment/vam/nongaseouspollutants/NPL_Report_DQL-AS015.pdf
Sample flow rates must be checked to ensure that the sample volume is accurately determined.

2.3 MONITORING SITE LOCATION

Local authorities should not be surprised if there are difficulties getting the equipment installed at the preferred location.

For automatic analyser enclosures visual impact and planning permission are always major issues. Noise may also be a consideration. Practical problems such as power and telephone connection, access and security may also limit your choice. Given that these concerns are satisfied, a monitoring site will be representative if it is:

- Not enclosed by surrounding buildings or covered by overhanging vegetation.
- Sampling air at a height of between 2 and 5 m.
- Not close to local or point source emissions unless these have been specifically targeted for investigation.

Guidelines site location specifications for urban background and roadside sites are provided in LAQM TG (03)

2.4 DURATION OF MONITORING

All surveys should ideally be carried out for a minimum of six months, three in the summer and three in the winter. For practical or budgetary reasons local authorities may only be able to carry out three-month surveys using automatic monitors. These still provide extremely useful information, in particular if levels can be compared with those from a nearby long-term air pollution monitoring site.

The length of a monitoring survey may also depend upon the type of objective against which you are comparing, and the results that you obtain. For comparison against the annual mean NO_2 objective a three month survey may be sufficient, whereas where you are trying to capture a peak concentration such as the 99.9th percentile of 15- minute means for SO_2 then ideally you would measure for a full 12 months.

Also, if after only three months monitoring concentrations have proved to be well below the objective then you could consider this to be sufficient data.

2.5 ACCREDITATION OF CALIBRATION STANDARDS AND QA/QC AUDITS

All automatic air monitors should be calibrated with a reliable zero air source and a cylinder of traceable, accredited span gas; a suitable calibration laboratory should verify these mixtures independently as the manufacturers' certificates may not always offer the accuracy and traceability required for the calibration of automatic monitoring instruments.

A high level of accuracy, precision and data capture is needed for Detailed Assessments. All calibration gases and analytical techniques applied to monitoring methods should be accredited to a recognised standard, for example, UKAS or ISO 17025

Gas cylinders at the low concentrations, required for calibrating ambient air monitoring analysers cannot be guaranteed to be stable over the long-term. Hence, It is recommended that the concentrations of these gases are checked by independent audit every six months, as in the national monitoring networks.

2.6 COST

The cost of an automated air quality monitoring programme will depend on many different factors, including location, range of pollutants monitored and of course the duration of the programme. We provide a range of scenarios here with approximate costs.

Project Task	Estimated Cost
Six-month to one year monitoring survey contracted "all-inclusive" to specialist consultancy.	**£10k - £25k** depending on duration, reporting requirements and number of pollutants.
Purchase and installation of single gas-analyser in existing building with power and phone line already available.	**£10k – £15k**
Purchase and installation of a particulate monitor in an existing building with power and phone line already available.	**£10k – £25k**
Purchase and installation of multi-pollutant site including PM_{10} in purpose-built enclosure. Power and phone to be connected, calibration gases to be purchased, data collection software to be purchased.	**£50k – £80k**
Annual "all-inclusive" service and maintenance costs.	**£3-8k** per site
Annual data management and QA/QC costs.	**£5-10k** per site
Annual staff costs for site visits.	**£5-10k** per site
Annual cost of electricity/phone.	**£2-3k** per site
Web site commissioning costs.	**£3-10k** depending on sophistication.
Annual software and web site maintenance fees.	**£1-2k**
Annual filter weighing costs for gravimetric PM10 monitoring.	**£3-10k** per year depending on number of filters, reporting requirements, source apportionment analysis.