

# using science to create a better place

## Review of background air-quality data and methods to combine these with process contributions

Science report: SC030174/1 SR1

The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

**Published by:**

Environment Agency, Rio House, Waterside Drive, Aztec West,  
Almondsbury, Bristol, BS32 4UD  
Tel: 01454 624400 Fax: 01454 624409  
[www.environment-agency.gov.uk](http://www.environment-agency.gov.uk)

ISBN: 1844325296

© Environment Agency

October 2006

All rights reserved. This document may be reproduced with prior permission of the Environment Agency.

The views expressed in this document are not necessarily those of the Environment Agency.

This report is printed on Cyclus Print, a 100% recycled stock, which is 100% post consumer waste and is totally chlorine free. Water used is treated and in most cases returned to source in better condition than removed.

Further copies of this report are available from:

The Environment Agency's National Customer Contact Centre by emailing [enquiries@environment-agency.gov.uk](mailto:enquiries@environment-agency.gov.uk) or by telephoning 08708 506506.

**Author(s):** John Stedman, John Abbott,  
Paul Willis, Jon Bower

**Dissemination Status:** Publicly available

**Keywords:**

Air, pollution, episodes, background, concentrations, ambient, monitoring, process, baseline, particles, modelling, industry, control, regulation, annual, mean, SO<sub>2</sub>, NO<sub>2</sub>

**Research Contractor:**

Netcen- AEA Technology, Harwell, Didcot, Oxfordshire

**Environment Agency's Project Manager:**

Dr. Hope Brett  
Environment Agency  
Lower Bristol Road  
Bath  
BA2 9ES

**Collaborator(s):** None

**Science Project reference:**  
SC030174/1 SR1

**Product code:** SCHO1205BKBN-E-P

# Science at the Environment Agency

Science underpins the work of the Environment Agency. It provides an up-to-date understanding of the world about us and helps us to develop monitoring tools and techniques to manage our environment as efficiently and effectively as possible.

The work of the Environment Agency's Science Group is a key ingredient in the partnership between research, policy and operations that enables the Environment Agency to protect and restore our environment.

The science programme focuses on five main areas of activity:

- **Setting the agenda**, by identifying where strategic science can inform our evidence-based policies, advisory and regulatory roles;
- **Funding science**, by supporting programmes, projects and people in response to long-term strategic needs, medium-term policy priorities and shorter-term operational requirements;
- **Managing science**, by ensuring that our programmes and projects are fit for purpose and executed according to international scientific standards;
- **Carrying out science**, by undertaking research – either by contracting it out to research organisations and consultancies or by doing it ourselves;
- **Delivering information, advice, tools and techniques**, by making appropriate products available to our policy and operations staff.



Steve Killeen

**Head of Science**

# Executive Summary

This is the final report for Task 1 of 3 of the Air Quality Umbrella R&D project “Background Pollution and Pollutants A–Z” awarded to Necten in 2004.

Effects-based approaches to the regulation of industrial pollution control require access to reliable information on the impacts of pollutants on the environment, as well as on the capacity of the receiving environment to accept pollutant loadings. The damaging loading for a given air pollutant will comprise a contribution from the particular process or plant under consideration, together with a background contribution that would be present even if the process or plant was not operating.

The overall aim of the report is to define a phased, hierarchical approach to guide decisions on the selection and combination of background concentrations within regulatory situations. The systematic approach we use is flexible and seeks to take into account the:

- ▶ risk of exceeding air-quality objectives;
- ▶ relative importance of the process and background contribution to the risk of exceeding objectives;
- ▶ need for the level of detail required in the assessment of background concentrations to be appropriate to each assessment.

The report should be read in conjunction with a companion technical report produced by Necten. This presents detailed case studies that tested current best practice for combining process and background concentrations for short-term concentration assessments. The methods outlined in the companion report are best-suited to typical industrial situations in which process contributions (PCs) dominate background concentrations in short-term assessments.

The methods reported here are intended to maintain the Environment Agency's awareness of the science of background air pollution, and to show approaches that could be used for particular regulatory applications (for example, in sensitive or complex cases). They are not intended to replace the Environment Agency's current normal operational procedures, but they should inform the longer-term development of such procedures, both in the Environment Agency and elsewhere.

We here list the pollutants considered in this study, together with the relevant environmental assessment levels. We go on to present the results of an assessment of the relative PCs to ambient concentrations at a wide range of monitoring locations.

We provide in the main text and appendices a concise summary of data-quality considerations and issues about monitoring site location. We then review in detail the possible methods to evaluate background concentrations for annual mean assessments. Corresponding methods to estimate background concentrations for

short-term assessments in typical industrial situations are then presented. Copious real-world monitoring data, plants and case studies are used throughout.

In Section 7, we provide for regulators a series of user-friendly checklists to aid decision-making on the selection of background concentrations.

# Contents

1	INTRODUCTION	1
1.1	Why information on background concentrations is required for industrial pollution control	1
1.2	A phased approach to the selection and use of background concentrations	1
1.3	Averaging times	2
1.4	Methods to assess background concentrations	3
1.5	The structure of this report	3
2	POLLUTANTS CONSIDERED IN THIS REPORT	5
2.1	Pollutants considered	5
2.2	Environmental assessment levels	5
2.3	Relevance to other pollutants	7
3	AN ASSESSMENT OF THE PROCESS CONTRIBUTION TO AMBIENT AIR POLLUTANT CONCENTRATIONS	8
3.1	Introduction	8
3.2	Modelling methods	8
3.3.1	NO <sub>x</sub> and PM <sub>10</sub>	9
3.3.2	SO <sub>2</sub>	10
4	MONITORING SITE LOCATIONS AND DATA QUALITY	19
4.1	Site location	19
4.2	Local siting criteria	20
4.3	Site numbers	21
4.4	Quality assurance and quality control	21
4.4.1	QA/QC of automatic monitoring data	21
4.4.2	QA/QC of non-automatic data	22
4.5	Monitoring period	23
4.6	Data capture	26
4.7	Setting up a monitoring survey	26
5	METHODS TO ESTIMATE BACKGROUND CONCENTRATIONS FOR ANNUAL MEAN ASSESSMENTS	27
5.1	Introduction	27
5.2	Typical concentrations	27
5.3	Indicative monitoring	28
5.4	Interpolation	28
5.5	Background maps	29
5.6	Automatic monitoring data	30
5.6.1	Introduction	30
5.7	Automatic data plus pollution roses	31
5.7.1	Introduction	31
5.7.2	Wind shear	31
5.7.3	Choosing which wind directions are influenced by a process	31
5.7.4	Example	32
5.8	Automatic data plus modelling	34
6	METHODS TO ESTIMATE BACKGROUND CONCENTRATIONS FOR SHORT-TERM ASSESSMENTS	35
6.1	Introduction	35
6.2	Comparison of annual mean and short-term process contributions	36
6.2.1	NO <sub>x</sub>	36
6.2.2	PM <sub>10</sub>	37
6.2.3	SO <sub>2</sub>	37
6.3	Comparison of annual mean and short-term ambient concentrations	38
vi	<b>Science Report SC030174/1 SR1:</b> Review of background air-quality data and methods to combine these with process contributions	

6.3.1	Introduction	38
6.3.2	NO <sub>2</sub>	38
6.3.3	PM <sub>10</sub>	40
6.3.4	SO <sub>2</sub>	41
6.3.4	Estimating percentiles from annual means	42
6.4	Automatic data: the baseline method of adding process and background contributions on an hourly basis	43
6.5	Automatic data: alternative methods for adding process and background contributions	43
6.5.1	Introduction	43
6.5.2	SO <sub>2</sub>	44
6.5.3	NO <sub>2</sub>	45
6.5.4	PM <sub>10</sub>	46
6.6	What to do if automatic data are not available	46
7	GUIDANCE	47
7.1	Introduction	47
7.2	General approach	47
7.2.1	General checklists (high, medium and low importance)	48
7.3	What statistics to collect	49
7.3.1	SO <sub>2</sub>	49
7.3.2	NO <sub>x</sub> /NO <sub>2</sub>	50
7.3.3	PM <sub>10</sub>	50
7.3.4	Benzene	50
7.3.5	BaP	51
8	REFERENCES	52
	APPENDIX A: DEFINITION OF SITE CLASSES	53
	APPENDIX B: SETTING UP A MONITORING CAMPAIGN	55

# 1 Introduction

## 1.1 Why information on background concentrations is required for industrial pollution control

Effects-based approaches to industrial pollution control require information about the impacts of pollutants on the environment and about the capacity of the receiving environment to accept pollutant loadings. In the case of discharges to air, the damaging loading for a given pollutant generally comprises a contribution from the particular process or plant under consideration, together with a background contribution that would be present even if the process or plant was not operating.

An essential element of an effects-based approach to industrial pollution control is the assessment of background concentrations of regulated pollutants. The predicted environmental concentration (PEC) is:

$$PEC = PC + \text{background concentration}$$

where PC is the process contribution. The PEC can then be compared with the environmental assessment level (EAL). The objective is that the PEC should remain below the EAL.

## 1.2 A phased approach to the selection and use of background concentrations

The overall aim of this report is to define a phased, hierarchical approach to guide decisions on the selection and combination of background concentrations within regulatory situations. The level of detail required in the evaluation of background concentrations should be appropriate to each assessment. Thus, this approach should take into account the:

- ▶ risk of exceeding air-quality objectives;
- ▶ relative importance of the process and background contribution to the risk of exceeding objectives.

It is clear that an air-quality assessment can give a number of possible results; the level of detail required to assess background concentrations will therefore vary. A number of possibilities are illustrated in *Table 1.1*, which has been colour coded to show the level of detail required to assess background concentrations (red, most detailed; green, least detailed).

**Table 1.1 Possible results of an air-quality assessment and the level of detail required to assess background concentrations**

PEC relative to EAL	PC relative to background	Notes
PEC > EAL, PC > EAL	PC >> background	PC above EAL, so there is an air-quality issue irrespective of the choice of background
PEC > EAL	PC >> background	If PC is below EAL, selection of background is important
PEC > EAL	PC similar to background	Selection of background is important
PEC > EAL	PC << background	PEC is dominated by background, so selection of background is important
PEC < EAL	PC >> background	PEC is dominated by PC, so selection of background is less important
PEC < EAL	PC similar to background	Selection of background is important, but less important than if PEC > EAL
PEC < EAL	PC << background	Selection of background is important, but less important than if PEC > EAL

The methods reported here are intended to maintain the Environment Agency's awareness of the science of background air pollution, and to show approaches that could be used for particular regulatory applications (for example, in sensitive or complex cases). They are not intended to replace the Environment Agency's current normal operational procedures, but they should inform the longer-term development of such procedures, both in the Environment Agency and elsewhere.

### 1.3 Averaging times

EALs may apply to long-term concentrations such as annual means, or to short-term concentrations such as hourly or daily means. It is clearly important that the estimates of both the PC and background concentration should match the averaging time of the EAL. For annual mean concentrations, it can be assumed that the annual means of the PC and background concentrations are additive. For short-term EALs, a detailed analysis requires the addition of PC and background concentrations on, for example, an hourly basis, or the selection of background concentration statistics appropriate for addition to estimates of high percentile PC. This is because:

- ▶ it is not physically meaningful to add percentiles of concentrations;
- ▶ the meteorological conditions that lead to high PC often do not coincide with those that lead to high background concentrations.

A detailed case study to test current best practice for combining process and background concentrations in short-term concentration assessments is presented in the accompanying technical report (Abbott *et al.*, 2005). The methods in the technical report are suited to typical industrial situations in which PCs dominate background concentrations.

## 1.4 Methods to assess background concentrations

Background concentrations can be assessed in a number of ways. In order of increasing complexity, these include:

- ▶ typical values;
- ▶ indicative measurements;
- ▶ interpolation;
- ▶ background maps;
- ▶ automatic monitoring data;
- ▶ automatic monitoring data with pollution rose analysis;
- ▶ automatic monitoring data with modelled PC subtracted.

The increase in availability of automatic monitoring data over recent years means that it is now more likely that automatic monitoring data can be used within an assessment of background concentrations. However, a number of issues have to be considered when using automatic monitoring data in this way, which include:

- ▶ matching the environment of the process and background measurements;
- ▶ distance from the process;
- ▶ monitoring method;
- ▶ quality assurance;
- ▶ data capture;
- ▶ avoiding double counting the PC.

## 1.5 The structure of this report

This report provides a discussion of some of the key issues to be considered in the selection and use of background concentrations for air-quality assessments. Where appropriate, we include illustrative examples and case studies for regulated processes in England and Wales. Some of the analyses of monitoring and modelling data include information from throughout the UK.

The sections are summarised as follows:

- ▶ **Section 2** lists the pollutants considered in this study, together with the relevant EALs.
- ▶ **Section 3** presents the results of an assessment of the relative PCs to ambient concentrations at a wide range of monitoring locations. If the PC is significant at a specific monitoring site location, ambient measurements at that location will not represent background concentrations, for which a more detailed assessment may be required.
- ▶ **Section 4** presents a summary of data-quality considerations and issues of monitoring site location.
- ▶ **Section 5** reviews the possible methods to evaluate background concentrations for annual mean assessments.
- ▶ **Section 6** reviews the possible methods to estimate background concentrations for short-term assessments in typical industrial situations.

- ▶ **Section 7** provides checklists to aid decision-making on the selection of background concentrations.

Detailed case studies to test current best practice in combining process and background concentrations for short-term concentration assessments in typical industrial situations are presented in the accompanying report (Abbott *et al.*, 2005).

# 2 Pollutants considered in this report

## 2.1 Pollutants considered

This report focuses on the regulated air pollutants listed below. They have been chosen to represent pollutants with a range of relative contributions from process and background concentrations. The list includes nitrogen dioxide (NO<sub>2</sub>) and particulate matter less than 10 micrometres in diameter (PM<sub>10</sub>), two of the pollutants for which the achievement of current objectives and limit values within the Air Quality Strategy is expected to be the most challenging.

- ▶ **sulphur dioxide** (SO<sub>2</sub>), a primary pollutant with significant PCs in some areas;
- ▶ **benzene** (C<sub>6</sub>H<sub>6</sub>), a primary pollutant with contributions from both process and background sources;
- ▶ **NO<sub>2</sub>**, a complex pollutant with both primary and secondary components. The dominant source is generally traffic emissions in urban areas;
- ▶ **PM<sub>10</sub>**, a complex pollutant with diverse source influences and both primary and secondary components;
- ▶ **benzo[a]pyrene** (BaP), a primary pollutant with significant PCs in some areas, but its overall source attribution is less certain than for many of the classic air pollutants.

## 2.2 Environmental assessment levels

The European Union limit values (EULV) and Air Quality Strategy (AQS) objectives for the pollutants considered in this study are listed in *Table 2.1*.

In most instances, the 15-minute mean EAL for SO<sub>2</sub> is likely to be the most stringent for this pollutant, although the 24-hour EAL may be more of an issue for processes with lower chimneys. The annual mean EAL for NO<sub>2</sub> is generally more stringent than the one-hour EAL. The annual mean EAL for NO<sub>x</sub> is more stringent, but only applies in ecosystem areas, which the EU First Daughter Directive defines as more than 5 km from industrial installations. The 24-hour 2005 PM<sub>10</sub> EAL is generally more stringent than the annual mean 2005 EAL. The 24-hour and annual mean 2010 are roughly equivalent in terms of stringency.

**Table 2.1 Environmental assessment levels**

Pollutant	EAL	Averaging period	Date to be achieved by	Status
<b>SO<sub>2</sub></b>	350 µg m <sup>-3</sup> not to be exceeded more than 24 times a year	One-hour mean	2005	EULV and AQS objective
	125 µg m <sup>-3</sup> not to be exceeded more than three times a year	24-hour mean	2005	EULV and AQS objective
	266 µg m <sup>-3</sup> not to be exceeded more than 35 times a year	15-minute mean	2005	AQS objective
	20 µg m <sup>-3</sup>	Annual mean	2001	EULV and AQS objective
	20 µg m <sup>-3</sup>	Winter mean	2001	EULV and AQS objective
<b>Benzene</b>	16.25 µg m <sup>-3</sup>	Running annual mean	2003	AQS objective
	5 µg m <sup>-3</sup>	Annual mean	2010	EULV and AQS objective
<b>NO<sub>2</sub></b>	200 µg m <sup>-3</sup> not to be exceeded more than 18 times a year	One-hour mean	2005	AQS objective
	200 µg m <sup>-3</sup> not to be exceeded more than 18 times a year	One-hour mean	2010	EULV
	40 µg m <sup>-3</sup>	Annual mean	2005	AQS objective
	40 µg m <sup>-3</sup>	Annual mean	2010	EULV
<b>NO<sub>x</sub></b>	30 µg m <sup>-3</sup> , as NO <sub>2</sub>	Annual mean	2001	EULV and AQS objective
<b>PM<sub>10</sub></b>	50 µg m <sup>-3</sup> not to be exceeded more than 35 times a year	24-hour mean	2005	EULV and AQS objective
	40 µg m <sup>-3</sup>	Annual mean	2005	EULV and AQS objective
	50 µg m <sup>-3</sup> not to be exceeded more than 10 times a year	24-hour mean, London	2010	AQS objective
	50 µg m <sup>-3</sup> not to be exceeded more than seven times a year	24-hour mean, rest of England and Wales	2010	AQS objective
	23 µg m <sup>-3</sup>	Annual mean, London	2010	AQS objective
	20 µg m <sup>-3</sup>	Annual mean, rest of England and Wales	2010	AQS objective
	50 µg m <sup>-3</sup> not to be exceeded more than seven times a year	24-hour mean	2010	Indicative EULV
	20 µg m <sup>-3</sup>	Annual mean	2010	Indicative EULV
<b>BaP</b>	0.25 ng m <sup>-3</sup>	Annual mean	2010	AQS objective
	1 ng m <sup>-3</sup>	Annual mean	2010	Proposed EU target value

## 2.3 Relevance to other pollutants

This study focussed on the assessment of the background concentrations of five selected air pollutants. However, the information it provides may also be of relevance to the assessment of the background concentrations of other air pollutants. The attributes that can be considered when comparing with the pollutants here are:

- ▶ averaging times of the relevant EALs (annual, hourly, daily, etc.);
- ▶ process release characteristics (tall chimneys, fugitive releases);
- ▶ local sources of background (are traffic or domestic emissions important?);
- ▶ long-range transport (is there a significant regional component to background?);
- ▶ chemical processes in the atmosphere (are these important?).

Some examples of other pollutants are listed in *Table 2.2*.

**Table 2.2 Relevance of the example pollutants described here to other AQS pollutants**

<b>1,3-butadiene</b>	Similar averaging time (annual mean) and sources to benzene (process and traffic contributions); fewer process sources than for benzene
<b>Carbon monoxide (CO)</b>	Sources similar to NO <sub>x</sub> (local traffic very important), but eight-hour mean averaging period
<b>Lead</b>	Annual mean averaging period; process emissions dominate, regional concentrations low
<b>PM<sub>2.5</sub></b>	Similar averaging times and characteristics to PM <sub>10</sub> (of which PM <sub>2.5</sub> is a component); regional contributions to background are important
<b>Polycyclic aromatic hydrocarbons (PAHs)</b>	Similar to BaP; BaP used as a marker within AQS

# 3 An assessment of the process contribution to ambient air pollutant concentrations

## 3.1 Introduction

This section describes an assessment of the magnitude of PCs to ambient concentrations. If the PC is significant at a specific monitoring site location, then ambient measurements at that location will not represent background concentrations unless steps are taken to avoid double counting (such as pollution rose analysis or subtraction of the modelled PC). The analysis presented here makes extensive use of the results of modelling work carried out by Netcen for the Department for Environment, Food and Rural Affairs (Defra). Specifically, we have used the pollution climate model results for 2003 concentrations prepared for EU Daughter Directive and Air Quality Strategy Objective reporting.

## 3.2 Modelling methods

The methods used to derive these maps are described in detail by Stedman *et al.* (2003). The maps were built up by combining the contributions to ambient concentrations from a number of different sources:

- ▶ **large point sources** – modelled explicitly using a dispersion model;
- ▶ **small point sources** – modelled using a generalised dispersion kernel approach;
- ▶ **area sources** – modelled using a dispersion kernel approach, calibrated using automatic measurements;
- ▶ **regional rural concentrations** – interpolated from rural measurements, corrected for local source contributions.

In the analysis presented here, we considered the modelled concentration footprints of the large and small point sources (Part A processes) and compared the total contribution from these regulated processes with the ambient concentrations measured during 2003. The number of sources considered for each pollutant is listed in *Table 3.1*, along with the emission threshold used to assign the sources to the large and small categories.

**Table 3.1 The number of point sources modelled**

Pollutant	Emission threshold (tonnes per year)	Number of large points	Number of small points
SO <sub>2</sub>	500	134	591
NO <sub>2</sub> (NO <sub>x</sub> )	500	170	923
PM <sub>10</sub>	200	63	1911

Annual mean concentrations of NO<sub>x</sub> and PM<sub>10</sub> were modelled, together with the annual mean, 99.9 percentile of 15-minute means, 99.73 percentile of one-hour means and 99.18 percentile of 24-hour means for SO<sub>2</sub>. A systematic review of the PCs to ambient concentrations at all Automatic Urban and Rural Network (AURN – a national monitoring network) and Joint Environmental Programme (JEP – sites close to power stations) sites was carried out for 2003.

We adopted a model-based approach, which is appropriate for:

- ▶ estimating the contribution to ambient concentrations from all of the point sources in the emission inventory;
- ▶ including in the maps of background concentrations throughout the UK.

Clearly, however, this approach involves a number of simplifications and assumptions and a better estimate of the PC could be obtained from a more detailed study for a single source, such as would be carried out for regulatory assessment. We are confident, however, that our approach is suitable for national reporting and assessment purposes and will also provide a reliable indication of locations with significant contributions from Part A processes. PC-to-ambient concentrations of greater than 100 per cent in the analysis presented here indicate that the PC has been overestimated in our analysis.

### 3.3.1 NO<sub>x</sub> and PM<sub>10</sub>

*Figure 3.1* shows the modelled PC to annual mean NO<sub>x</sub> concentrations at background AURN monitoring sites (all sites except roadside and kerbside sites). The modelled PC is less than 1 µg m<sup>-3</sup> as NO<sub>2</sub> at the majority (64 per cent) of the sites and less than 4 µg m<sup>-3</sup> as NO<sub>2</sub> at all but three sites. *Figure 3.1* also shows the PC as a percentage of the measured annual mean concentrations. The ranking is generally similar to the modelled PC, although the percentage PC is higher at some rural monitoring sites, such as Ladybower, Narberth and Rochester. The dominant source of ambient NO<sub>x</sub> in most locations is road traffic; the magnitude of this source is generally greatest in urban areas or in the vicinity of major roads.

Several notable NO<sub>x</sub> sources are associated with the highest PCs. At Port Talbot, two large sources are owned by the Corus steel works. In addition to these two sources, Baglan Operations own a plant nearby. The most significant NO<sub>x</sub> process source close to Billingham is Terra Nitrogen. The most important process sources close to Rochester are at Damhead Creek and Medway and Kingsnorth power stations.

*Figure 3.2* shows the modelled PCs to annual mean PM<sub>10</sub> concentrations at AURN sites. The contribution is less than 0.5 µg m<sup>-3</sup> at the majority (73 per cent) of sites, which represents less than 2.5 per cent of the measured concentration at most locations.

At the AURN Port Talbot monitoring site, the PC is calculated to be 9.5 per cent. A stack owned by Corus steel works in close proximity to the monitoring site is the most significant source contributing to PM<sub>10</sub> levels. There are also a number of Corus owned processes at Teesside, which help to account for the notable PC (4.1 per cent) at the AURN Redcar monitoring station, illustrated in *Figure 3.2*.

The PC at Scunthorpe is also notable, although ranked sixth in terms of percentage contribution to monitored annual mean. The sources associated with this high PC are, again, Corus-owned steel works.

*This analysis suggests that data from the majority of the AURN monitoring sites considered here are suitable to assess background concentrations of annual mean  $NO_x$  and  $PM_{10}$  in regulatory assessment, without the need for additional calculations to avoid double counting the PC. Figure 3.3 shows that this is also the case for annual mean  $NO_x$  at the majority of the JEP monitoring sites, which are located close to coal-fired power stations. The PC is less than 10 per cent at most of the monitoring sites, while the PC is estimated to be less than  $3 \mu\text{g m}^{-3}$  as  $NO_2$  at all of the sites.*

### 3.3.2 $SO_2$

Regulated processes typically make a larger percentage contribution to annual mean  $SO_2$  concentrations, as is clearly illustrated in Figure 3.4. *It is evident from this analysis that the subtraction of the PC from ambient concentrations may be required before the data from a number of these sites could be considered to represent background concentrations reasonably.* Ambient concentration measurements are, however, still a valuable source of information on background  $SO_2$  concentrations. This is because the background concentration relevant to the assessment of a particular process is likely to include contributions from many other processes. Figure 3.5 shows the modelled 99.9 percentile of 15-minute mean  $SO_2$  concentrations, together with this modelled value as a percentage of the measured 99.9 percentile. These figures illustrate the significant contribution of regulated processes to the high percentile  $SO_2$  concentration at some sites.

Notable PCs to the 99.9 percentile  $SO_2$  concentrations in England and Wales are at Narberth, Cardiff and Sunderland (Figure 3.5). The most significant sources near Narberth are the Elf oil refinery at Milford Haven and the Texaco oil refinery at Pembroke. Near Cardiff there is a process owned by Blue Circle Industries, at Aberthaw, and a power station owned by Innogy plc. Two notable sources exist in close proximity to the Sunderland air-monitoring site – a process owned by Lafarge Aggregates at Thirslington and one owned by the Alcan Primary Metal Group.

Figure 3.6 shows that the modelled 99.18 percentile of 24-hour mean  $SO_2$  concentrations can be a significant proportion of the measured concentration at some locations. The relative proportion of the PC to the ambient concentration measurement is intermediate between those for the annual mean and the 15-minute mean percentile.

Figures 3.7 and 3.8 illustrate that, as expected, regulated process emissions can contribute significantly to the measured annual mean and high percentile  $SO_2$  concentrations in the vicinity of power stations.

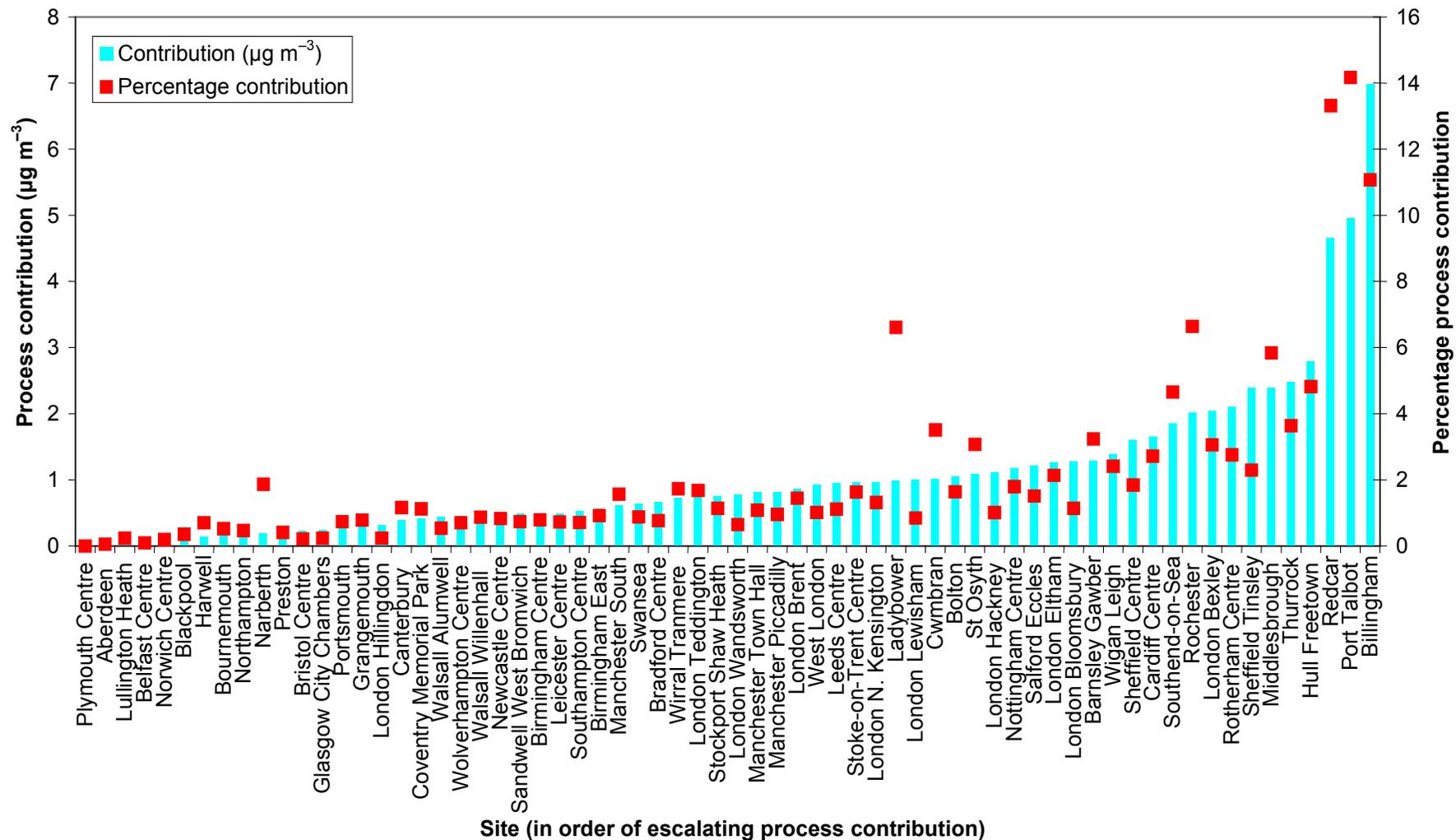


Figure 3.1 Process contribution at AURN background sites,  $\text{NO}_x$  annual mean, 2003

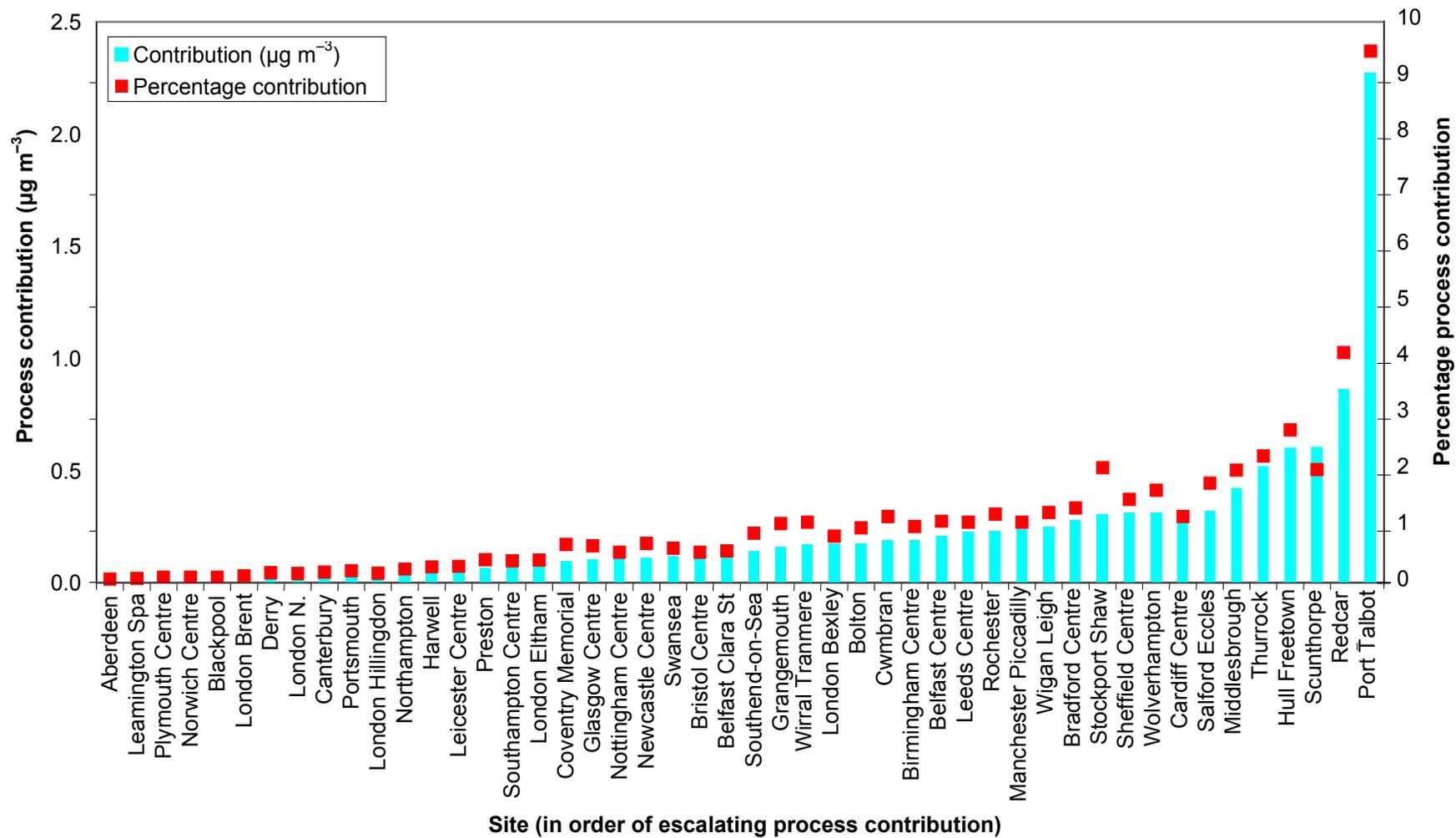
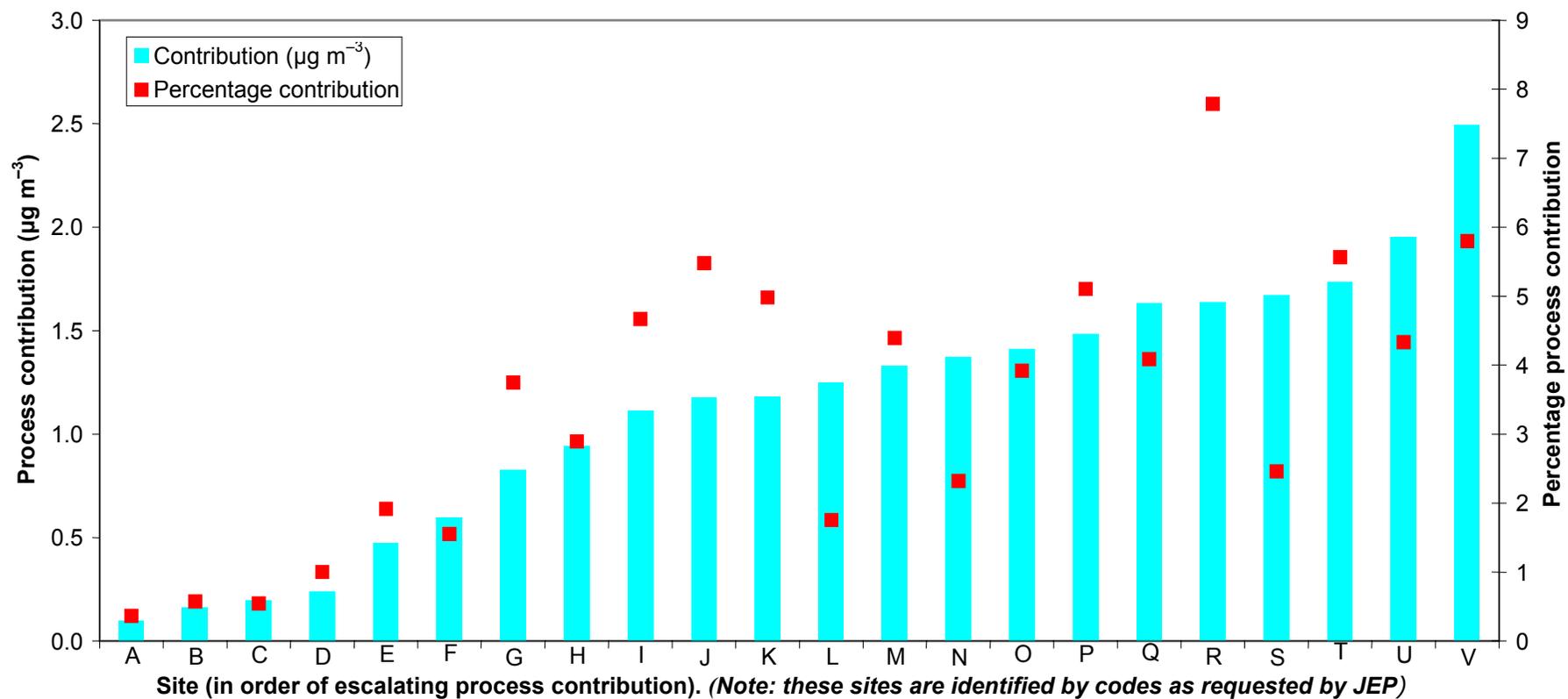


Figure 3.2 Process contribution at AURN background sites, PM<sub>10</sub> annual mean, 2003



**Figure 3.3 Process contribution at JEP sites, NO<sub>x</sub> annual mean, 2003**

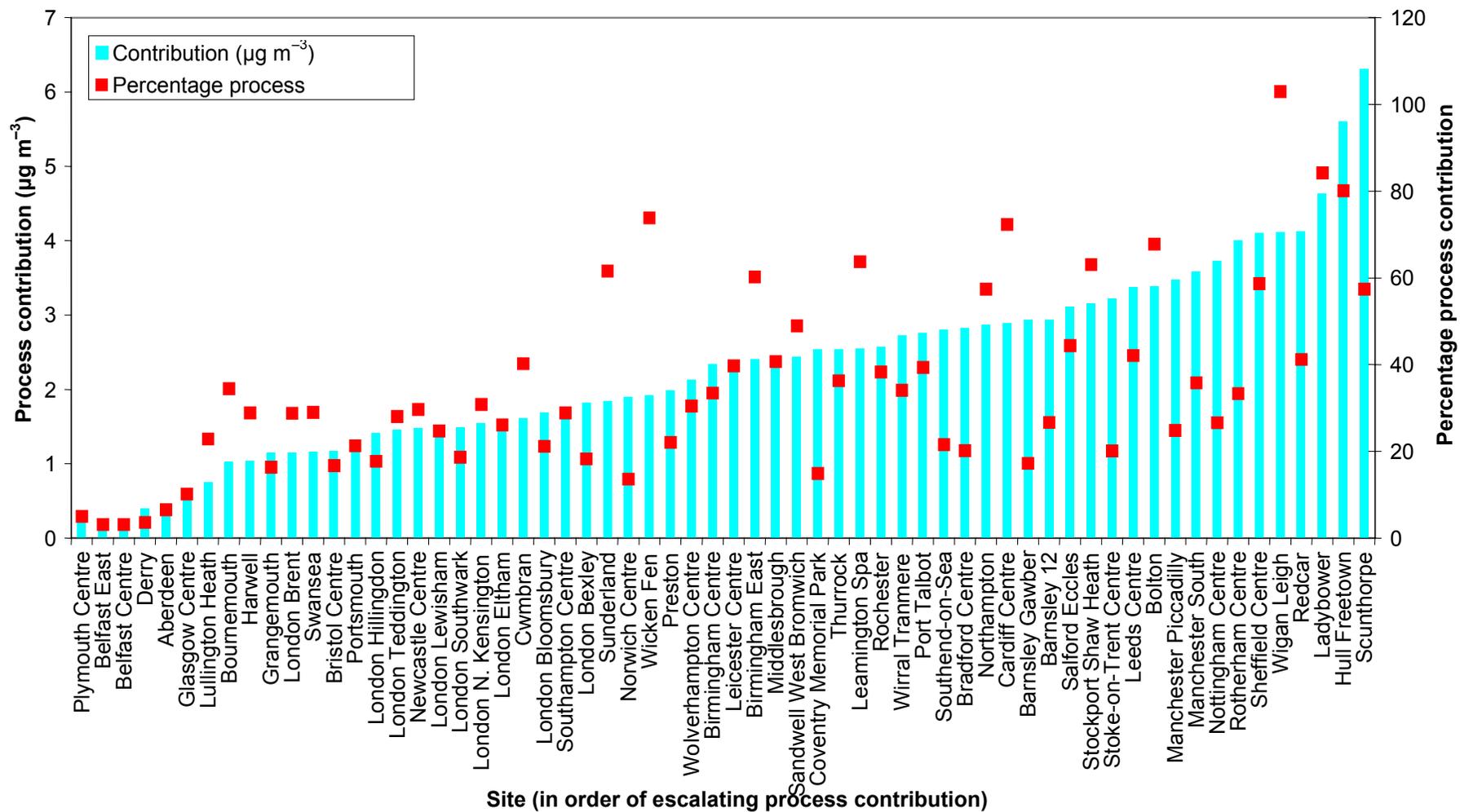


Figure 3.4 Process contribution at AURN background sites, SO<sub>2</sub> annual mean, 2003

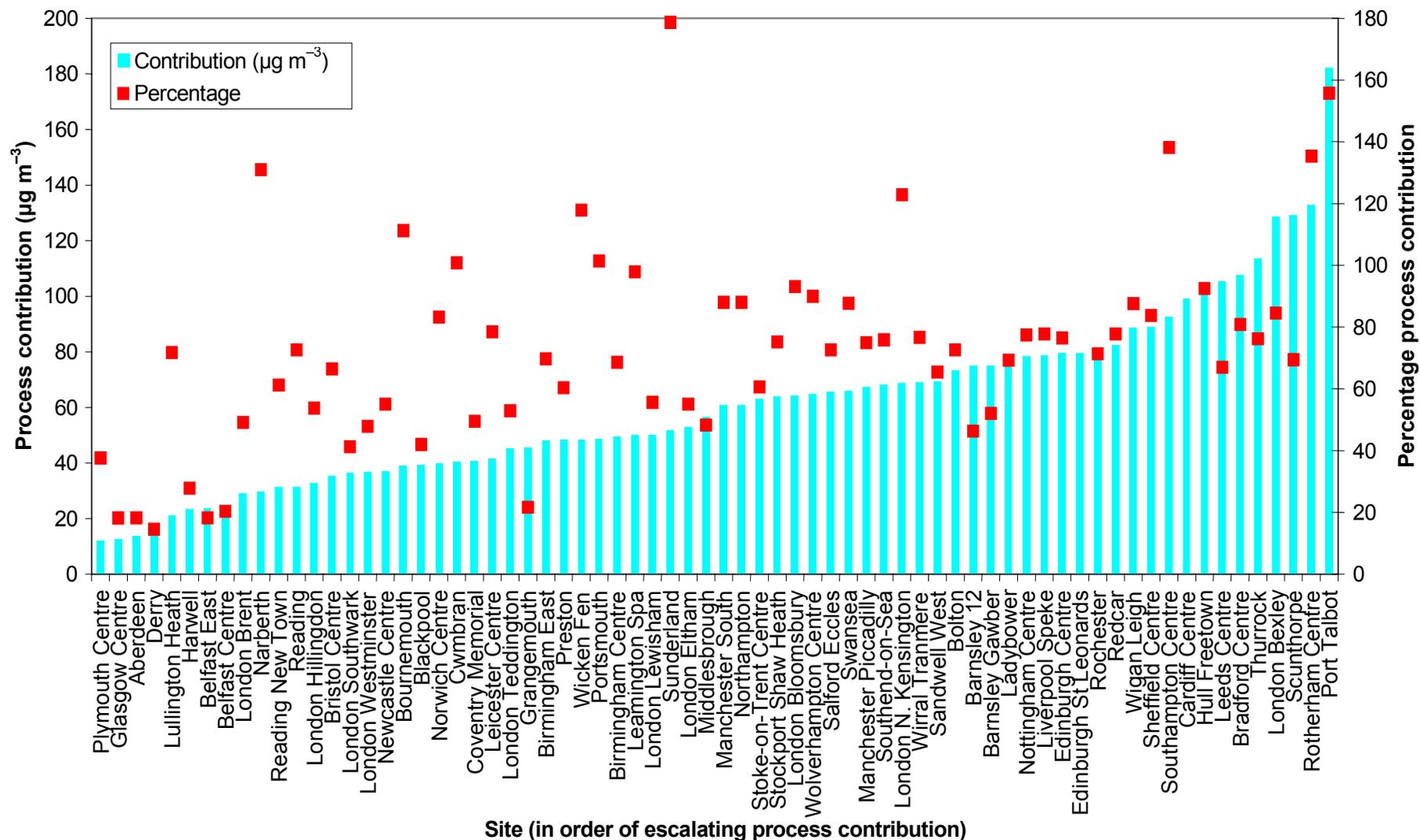


Figure 3.5 Process contribution at AURN background sites, SO<sub>2</sub> 99.9 percentile of 15-minute means

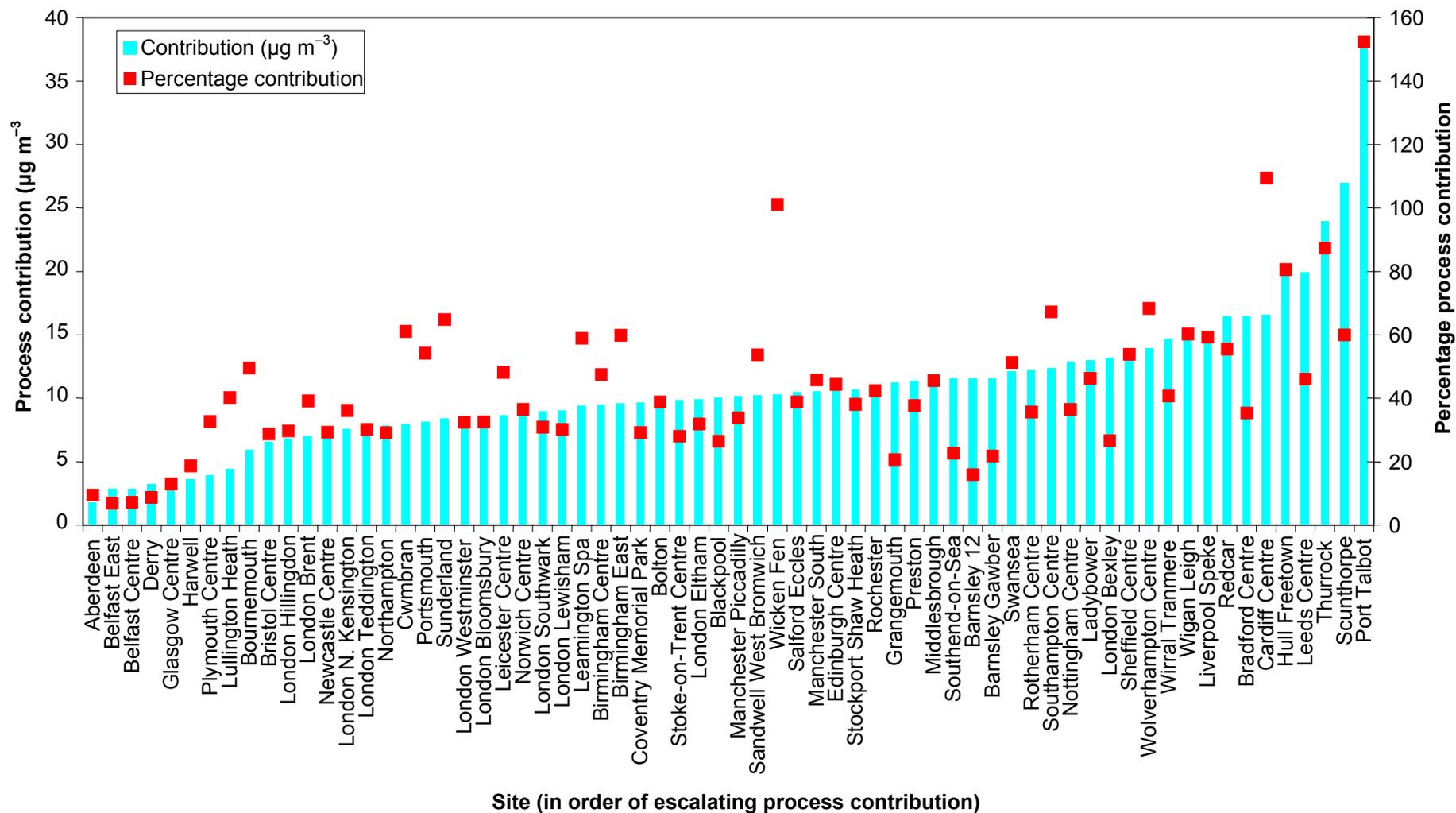
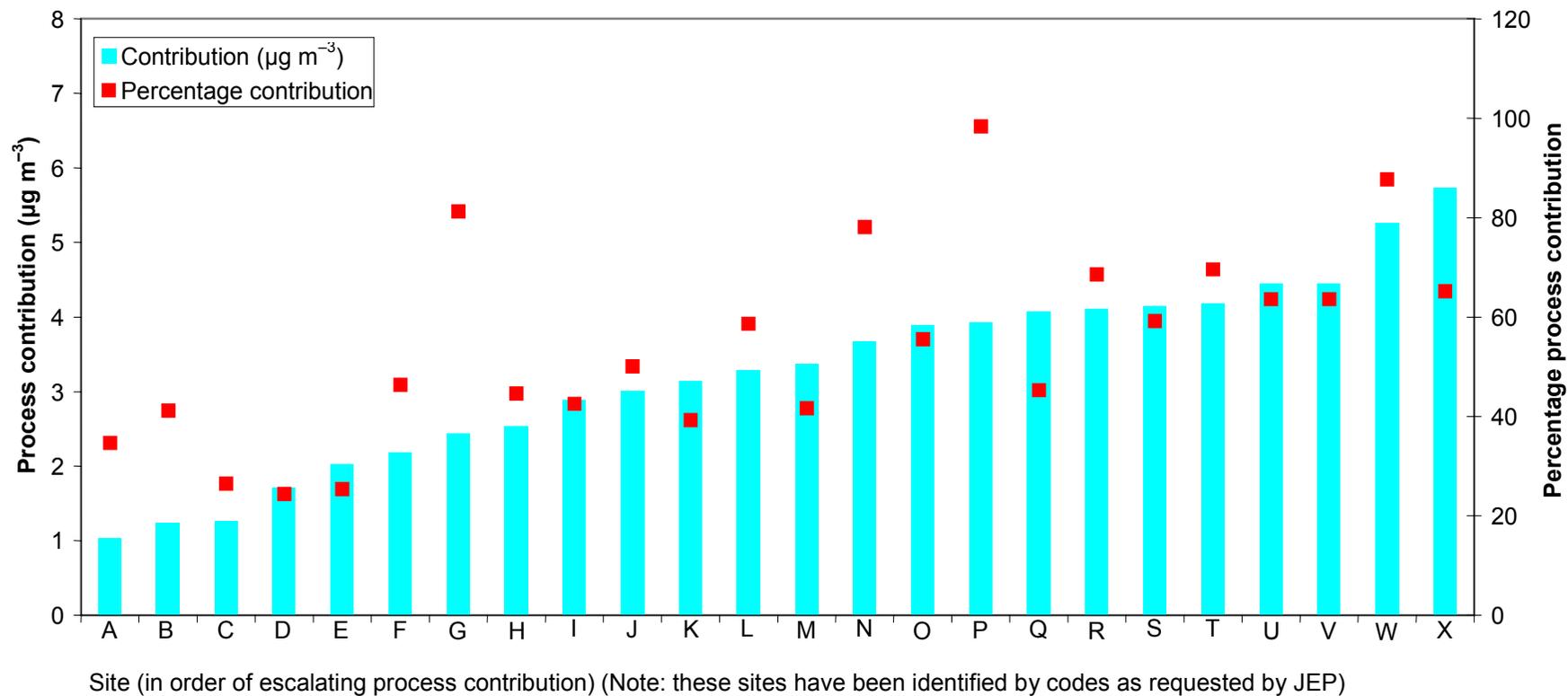
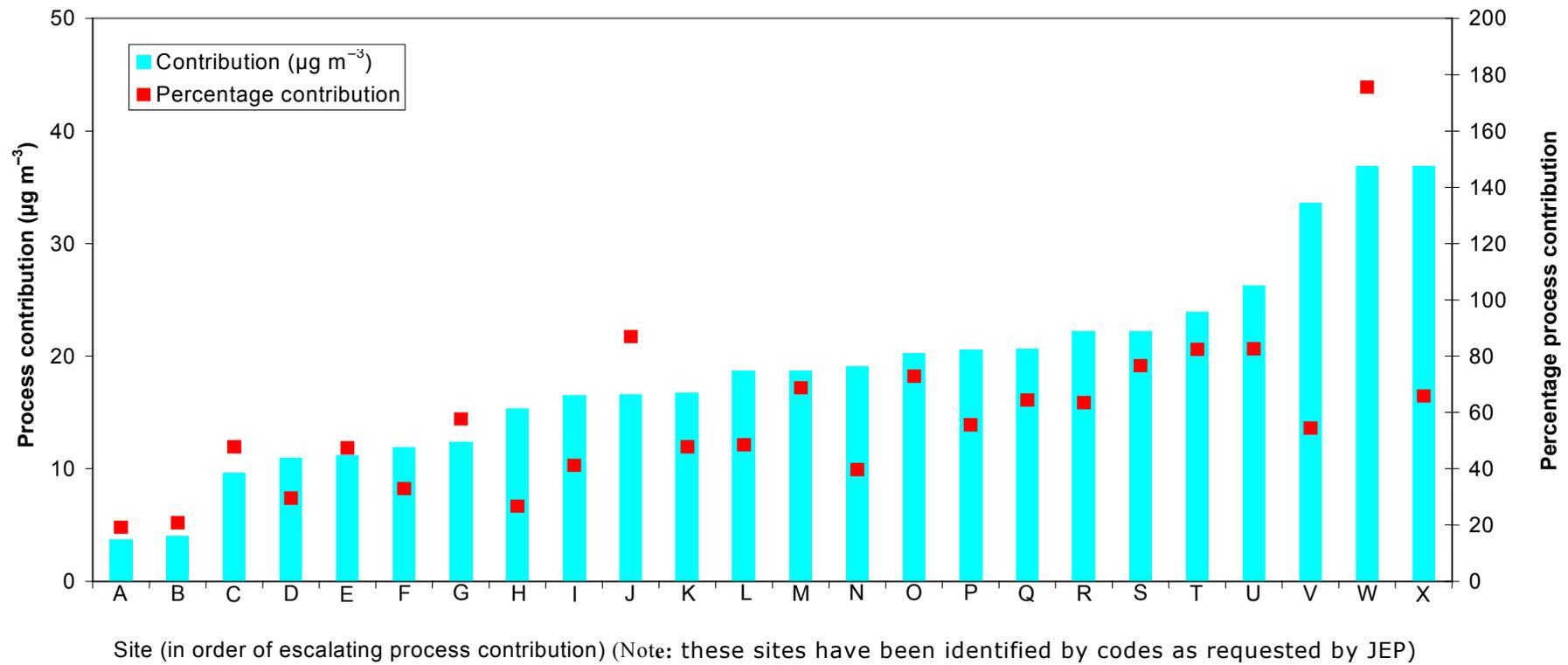


Figure 3.6 Process contribution at AURN background sites, SO<sub>2</sub> 99.18 percentile of daily means



**Figure 3.7 Process contribution at JEP sites, SO<sub>2</sub> annual mean, 2003**



**Figure 3.8 Process contribution at JEP sites, SO<sub>2</sub> 99.18 percentile of daily means, 2003**

# 4 Monitoring site locations and data quality

This section examines the major issues that need to be considered when reviewing or analysing data from an air-quality monitoring survey. To assess their utility and appropriateness for regulatory use, it is important to be aware of the characteristics and limitations of such data.

## 4.1 Site location

The first and most important question to ask about monitoring data is:

*What type of monitoring site location does this come from?*

The location type will determine whether the data can be used to investigate:

- ▶ population exposure;
- ▶ near-source peak ambient concentrations, for example near roads or industrial plants;
- ▶ rural background concentrations, for example as input to modelling studies, or to assess ecosystem affects.

Monitoring sites have been given a standard classification in the UK, according to the type of environment in which they are located. If this classification can be used in all reports, this introduces a degree of comparability and consistency that permits a more meaningful evaluation of the results. The standard site description generally reflects the influence of a particular pollutant source or of the overall land use. The descriptions used in the national automatic monitoring networks, and encouraged for review and assessment and all other scientific studies in the UK, are shown in *Table 4.1*.

**Table 4.1 Characteristic UK location types for monitoring sites**

Site type	Description
<b>City/urban centre</b>	An urban location representative of typical population exposure in towns or city centres, for example pedestrian precincts and shopping areas
<b>Urban background</b>	An urban location distant from sources and therefore broadly representative of city-wide background conditions, for example urban residential areas
<b>Suburban</b>	A location type situated in a residential area on the outskirts of a town or city
<b>Roadside</b>	A sampling site between 1 m of the kerbside of a busy road and the back of the pavement; typically, this will be within 5 m of the road, but could be up to 15 m
<b>Kerbside</b>	A sampling site within 1 m of the kerb of a busy road
<b>Industrial</b>	An area in which industrial sources are an important contributor to the total pollution burden
<b>Rural</b>	An open countryside location, in an area of low population density as far distant as possible from roads, populated and industrial areas
<b>Other</b>	Any special source-orientated or location category that covers monitoring undertaken in relation to specific emission sources, such as power stations, car parks, airports or tunnels

More detailed definitions of site classification types are provided in Appendix A. It is important that detailed descriptions of all monitoring site locations are given in air-quality reports, including distance from pollutant sources.

## 4.2 Local siting criteria

While the standard site-classification scheme provides some consistency between monitoring studies, it must be recognised that other local factors may affect the monitoring results. *Box 4.1* gives a list of local siting criteria. If it is known that any of these criteria are breached at a monitoring site, this should be noted, as it could mean the monitoring data are not representative because:

- ▶ the site is shielded from nearby pollution sources which should be influencing it;
- ▶ the site is in an enclosed space in which pollution can build-up and concentrations are not therefore representative of the surrounding area;
- ▶ the site is unduly influenced by very local sources – such as idling delivery vehicles — which it was not set up to assess;
- ▶ the site is influenced by large medium- or long-range sources that it was not intended to assess;
- ▶ The site is not in the pollution hotspot as intended.

### **Box 4.1 Local siting criteria**

- ▶ The monitoring location should be in as open a setting as possible in relation to surrounding buildings.
- ▶ Immediately above should be open to the sky, with no overhanging trees or buildings.
- ▶ The sample intake should be no higher than 10 m above local ground level and ideally between 1.4 and 4 m.
- ▶ For urban centre or background sites:
  - No major sources of pollution should be within 50 m, for example a large multi-storey car park;
  - No medium-sized sources should be within 20 m, for example petrol stations, ventilation outlets to catering establishments, etc.;
  - Cars, vans and/or lorries should not be expected to stop with their engines idling within 5 m of the sample inlet;
  - The site should not be within:
    - 30 m of a very busy road (>30,000 vehicles per day)
    - 20 m of a busy road (10,000-30,000 vehicles per day)
    - 10 m of any other road (<10,000 vehicles per day)
  - The surrounding area, within say 100 m, should not be expected to undergo major redevelopment, so as to avoid disruption and to allow long-term trends to be followed.
- ▶ For traffic-related sites:
  - The site should be within 1 m of the kerb (kerbside sites);
  - The site should be within 1-5 m of the kerb (roadside sites).
- ▶ For industrial sites:
  - If a specific source is being targeted, the site should ideally be at the point of maximum impact, as determined by modelling.

## 4.3 Site numbers

A second important question to consider when evaluating and analysing monitoring data is:

*Are there sufficient monitoring points in the area to determine accurately the spatial distribution of the pollutants?*

The number of monitoring stations and their accuracy determine the type of data analyses that can be carried out.

It may be that there is good spatial coverage of the area using low-cost samplers, such as diffusion tubes, daily smoke and SO<sub>2</sub> monitors or portable electrochemical monitors. While not the most accurate monitoring methods, and perhaps only providing monthly mean or daily data, these results are invaluable for reporting annual mean concentrations, comparing with annual mean limit values and objectives, and determining the spatial distribution of annual mean concentrations. These data can also be used to help calibrate dispersion modelling of annual mean concentrations across an urban area or around an industrial plant.

Highly accurate automatic monitors may be used to record data on an hourly basis at relatively few – possibly one or two – sites across an area. These data can be used to analyse and report peak concentrations and pollution episodes, and to compare with the limit values and objectives for both short-term averaging periods and long-term means. They will also be useful to calibrate dispersion modelling of peak concentrations. Generally, it is advisable to obtain high-resolution, accurate monitoring data for both background and 'hot spot' locations, to model accurately the distribution of the peak concentrations.

Accuracy of the data will depend on the application of appropriate QA/QC procedures. The level of QA/QC needs to be assessed before reporting data. This important issue is discussed further in the next section.

## 4.4 Quality assurance and quality control

It is important to assess the quality of any data being used for regulatory analysis or reporting. Assuming that the monitoring equipment itself is appropriate, the accuracy of the results will depend upon the quality assurance and quality control (QA/QC) procedures implemented in operating the monitoring stations. Documentation should be provided as evidence to support these QA/QC procedures, together with proof that they are actually being used on a routine basis. Below we provide some details of typical QA/QC requirements for automatic and sampler-based monitoring.

### 4.4.1 QA/QC of automatic monitoring data

Typical QA/QC programmes include an established schedule of regular site calibrations, validation of data and documentation of all procedures. Details of site quality assurance procedures for automatic monitoring are given in the UK Automatic Network Site Operator's Manual.

<http://www.aeat.co.uk/netcen/airqual/reports/lsoman/lsoman.html>.

The fundamental aims of a QA/QC programme are to ensure that:

- ▶ data should be representative of ambient concentrations that exist in the area under investigation;
- ▶ measurements need to be sufficiently accurate and precise to meet the defined monitoring requirements;
- ▶ data must be inter-comparable and reproducible;
- ▶ results from multi-site networks need to be internally consistent and comparable with national, international or other acceptable standards;
- ▶ measurements should be consistent over time, particularly if long-term trend analysis is to be undertaken.

#### **4.4.2 QA/QC of non-automatic data**

Although active and passive samplers are relatively simple to use, careful attention must be paid to QA/QC procedures to ensure that the data obtained are of defined and adequate quality. It is important that there are proper records of sample identifications, exposure dates and times. Any quality assurance and control programme must also include QA/QC of the subsequent laboratory analyses of samples collected.

##### ***Passive samplers***

Quality assurance of the analysis of diffusion tubes includes activities such as use of analytical and field blanks, checking the dimensions of the tubes and preparation of quality control charts for the analysis. Analytical laboratories should be accredited to a recognised standard, for example Work Place Assessment Scheme for Proficiency (WASP), United Kingdom Accreditation Service (UKAS) or European standard EN 45001. For detailed monitoring, diffusion tube data must be validated by a co-located automatic monitor.

Details of diffusion tube monitoring procedures are given in the UK NO<sub>2</sub> Diffusion Tube Network Instruction Manual, <http://www.airquality.co.uk/reports/no2man/no2man.html>

##### ***Active samplers***

For active sampling systems, there should be evidence of regular calibration of the volume or flow-metering device and the sampling and/or analytical procedures. Gas meters used to determine sample volume, or flow meters used to check flow rate, should be calibrated against primary standards before use, and regularly thereafter.

##### ***Gravimetric particulate samplers***

When using PM<sub>10</sub> 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 balance calibrated to national standards. Sample flow rates must be checked to ensure that the sample volume is accurately determined.

## 4.5 Monitoring period

It is important to know the duration of a monitoring program, to make sense of the results it has produced. If a data user is simply provided with an 'average' concentration for a given location, this has little meaning without details of the start and end date of the survey.

Depending on the length of the survey, the data can be used 'as found', or may need adjustment to convert it into an approximate annual mean or other relevant statistic.

It is also important to know whether the survey was carried out recently, or several years or months in the past, and then to obtain generic information about whether the monitoring period was generally high, low or average in terms of the overall pollution climate.

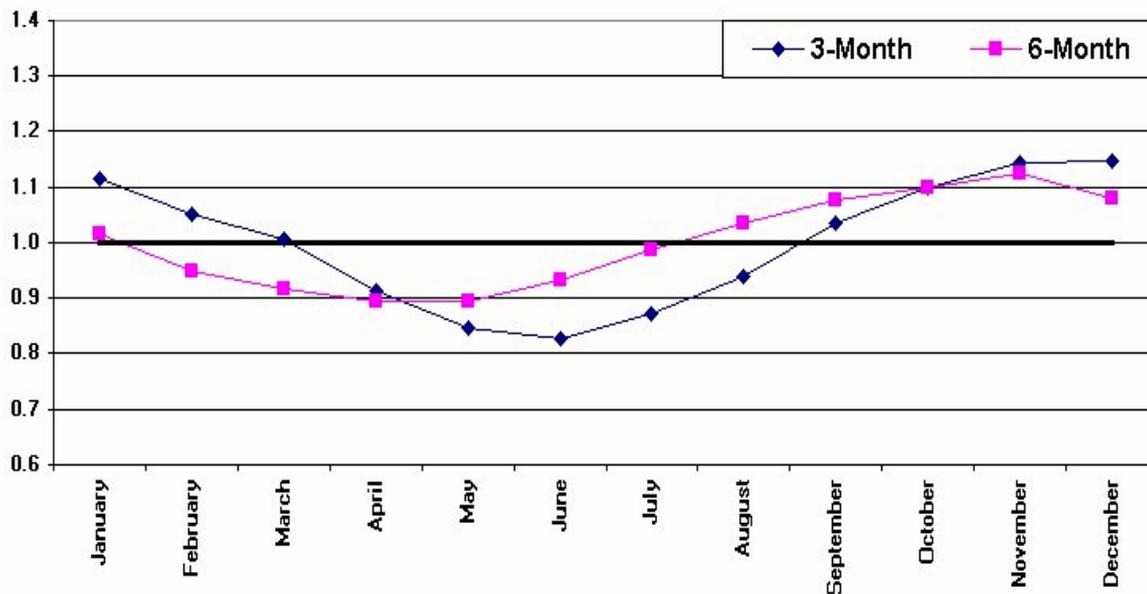
In an ideal world, air pollution monitoring surveys should be carried out for as long a period as possible. However, time or financial constraints mean that this is often not the case. Long-term surveys are particularly useful because:

- ▶ multi-year surveys are useful to identify trends in ambient pollutant concentrations at fixed locations;
- ▶ a full year of monitoring gives a direct comparison of the results with the averaging periods of the Air Quality Strategy objectives.

In reality, many surveys are carried out for a minimum of six months, three in the summer and three in the winter, consecutively (for example, January to June). For practical or budgetary reasons, surveys that use automatic monitors in particular may only be carried out for a relatively short period. These still provide extremely useful information, particularly if levels can be compared with those from a nearby long-term air-pollution monitoring site.

An examination of the ratio of short-term to long-term average measurements at urban background sites shows that for NO<sub>2</sub>, a six-month monitoring campaign will provide the most accurate estimate of the annual mean if started in January or July, and a three-month campaign in March or September. Measured six-monthly means show an average variability from the annual mean of up to 15 per cent and, for the three-month means, up to 20 per cent (*Figure 4.1*).

For carbon monoxide (CO) or SO<sub>2</sub>, it is generally best if a short-term monitoring campaign covers the winter months, when concentrations are highest. Equivalent PM<sub>10</sub> ratios do not show a marked seasonal variability.



**Figure 4.1 Ratio of short-term to annual means for nitrogen dioxide, urban non-roadside site**

The utility of data from a short-term monitoring survey clearly depends upon:

- ▶ the pollutant being measured;
- ▶ whether peak or mean concentrations are of interest.

For annual mean NO<sub>2</sub>, a three-month survey may provide a good estimate; by contrast, a reliable quantification of a peak estimate such as the number of 15-minute mean exceedances for SO<sub>2</sub> would ideally need 12 consecutive months of measurement.

If long-term data sets are available from a nearby monitoring network, it should be possible to estimate annual means from short-term data sets. An example of how to do this is given in *Box 4.2*. However, to produce any meaningful relationships between short- and long-term data sets requires detailed statistical analysis; moreover, previous studies have shown that derived scaling factors can be subject to considerable error. The longer the monitoring period used, the smaller the error in the derived scaling factor.

## Box 4.2 An example of estimating a long-term average from a short-term set of measurements

### Estimation of annual mean from short-period surveys

#### Example

It is only possible to carry out a monitoring survey at site S for three months between September and November 2002. The measured mean concentration of NO<sub>2</sub>,  $M$ , for this period is 38.0  $\mu\text{g m}^{-3}$ . How can this be used to estimate the annual mean for this location?

(This result could come from a chemiluminescence monitor or from a bias-adjusted diffusion tube.)

#### Adjustment to estimate annual mean

The adjustment is based on the fact that patterns in pollutant concentrations usually affect a wide region. Thus, if a three-month period is above average at one location, it will almost certainly be above average at other locations in the region. The adjustment procedure is as follows:

1. Identify 2-4 nearby long-term monitoring sites, ideally those that form part of the national network. Ideally, these should be background sites to avoid any very local effects. (These sites could be up to 50 miles away, depending on what is available.)
2. Obtain the annual means,  $A_m$ , for the previous calendar year for these sites, 2001 in this example.
3. Work out the period means,  $P_m$ , for the period of interest, in this case September to November 2002. (It may be necessary to use unratified data.)
4. Calculate the ratio,  $R$ , of the annual mean to the period mean ( $A_m/P_m$ ) for each of the sites.
5. Calculate the average of these ratios,  $R_a$ . This is then the adjustment factor.
6. Multiply the measured period mean concentration  $M$  by this adjustment factor  $R_a$  to give the estimate of the annual mean.

Long-term site	A	B	C	D	Average ( $R_a$ )
Annual mean 2001 ( $A_m$ )	50.5	32	28.9	33.7	
Period mean 2002 ( $P_m$ )	52	34.5	29.9	35.9	
Ratio ( $R$ )	0.971	0.928	0.967	0.939	0.951

For this example, the best estimate of the annual mean for site S is  $M \times R_a = 38.0 \times 0.951 = 36.1 \mu\text{g m}^{-3}$ .

## 4.6 Data capture

It is important to know what percentage of valid data have been captured during a monitoring survey, and whether the missing data are distributed randomly throughout the period, or in large blocks or at certain times of the day (that is whether the data are temporally biased).

For national automatic monitoring networks, the required data capture target has been set at 90 per cent over the course of a calendar year. The loss of only 10 per cent of monitoring data is a challenging target, as this includes routine data losses caused by site calibrations and servicing, as well as losses due to instrument faults or simply poor-quality data.

In the event that 90 per cent data capture is not achieved during a monitoring campaign, the monitoring results may still be useful, but problems of data quality have to be suitably flagged. The actual data capture rate should also always be reported.

For national monitoring networks, the following flags for data capture have been suggested:

- ▶ 25-50 per cent Flag C
- ▶ 50-75 per cent Flag B
- ▶ >75 per cent Flag A

For non-automatic monitoring networks, it is equally important to aim for a high data capture. For these networks, it is also vital to ensure that an effective QA/QC scheme is in place, as the loss of just a few sampling periods can reduce the data capture dramatically.

## 4.7 Setting up a monitoring survey

If an organisation is to establish a monitoring survey from scratch, there are further practical details to consider in addition to the issues that affect suitability of data discussed above. Additional guidance is presented separately in Appendix B to this report.

# 5 Methods to estimate background concentrations for annual mean assessments

## 5.1 Introduction

The different methods available to estimate annual mean background concentrations are described in this section. The strengths and weakness of these are discussed, together with key issues that need to be considered when using them.

## 5.2 Typical concentrations

The use of a typical background value within a regulatory assessment is appropriate where a detailed assessment of the background concentration is not required. This would be the case when the PC is considerably higher than the tabulated background concentration and the PEC is well below the EAL. If the background concentration is a large proportion of the PEC or, indeed, of the EAL, a more detailed assessment of the background concentration is required (for example, for NO<sub>2</sub> in a city centre location).

A check on the availability of automatic monitoring data in the vicinity or at locations relevant to the assessment is recommended in all instances, since this generally provides a more reliable estimate than a typical value. Alternatively, further information on the range of measured background concentrations can be found in UK Air Pollutants: key facts and monitoring data (Targa *et al.*, 2005).

It is important to match the environment within the footprint with the descriptions in *Table 5.1* when using typical background values. There may be more than one environment within the footprint.

It is unlikely that double counting of the local PC will be an issue when using typical background values. Clearly, typical background values will not include a specific component from the local process or processes and should only be used where the PEC is well below the EAL.

**Table 5.1 Suggested typical background annual mean concentrations for regulatory air-quality assessments, 2003 ( $\mu\text{g m}^{-3}$ )<sup>1</sup>**

Pollutant	City centre	Urban	Rural
SO <sub>2</sub>	8	7	4
NO <sub>2</sub> (NO <sub>x</sub> )	36	31	14
NO <sub>x</sub>	71	54	18
PM <sub>10</sub> (2002) (TEOM) <sup>2</sup>	20 (18)	18.5 (17)	16 (13) <sup>3</sup>
Benzene	1.2	1.5	0.6
BaP <sup>4</sup>	0.15	0.15	0.05

### Notes

1 Typical values were derived as the mean concentrations measured at AURN sites in the UK in 2003. The values for city centres were derived from urban centre sites, the values for urban locations were derived from urban background and suburban sites and the values for rural areas were derived from rural and remote sites. Outliers, such as urban background or urban centre sites close to roads, were excluded.

2 PM<sub>10</sub> concentrations measured using tapered element oscillating microbalance (TEOM) instruments x 1.0; concentrations were unusually high in 2003; 2002 values are included in brackets for comparison.

3 Rural PM<sub>10</sub> concentrations are highest in the south east and lowest in the north west of the UK. Rural concentrations in the UK in 2003 ranged from 12 to 19  $\mu\text{g m}^{-3}$  TEOM.

4 BaP concentrations in  $\text{ng m}^{-3}$ ; urban concentrations can be much higher (up to 1.0  $\text{ng m}^{-3}$ ) in areas with significant coal use for domestic heating.

## 5.3 Indicative monitoring

Results from indicative monitoring techniques can be used to provide estimates of background concentrations for regulatory assessments. Diffusion tubes can be used to measure annual mean NO<sub>2</sub> concentrations and bubblers can be used to provide annual and daily mean SO<sub>2</sub> concentrations. Where possible, automatic monitoring data should always be used in preference to data from indicative monitoring measurements, because of the greater uncertainty and lower temporal resolution of indicative measurements. It is particularly important to consider data quality and data capture issues (as discussed in Section 4) when using data from indicative measurements.

## 5.4 Interpolation

Interpolation methods, such as krigging, spline and inverse distance weighting, can be used to estimate background concentrations at locations where monitoring data are not available. Site environment and representativeness are particularly important issues when interpolation to estimate background concentrations is considered. Interpolation is most appropriate for rural locations where there are few local sources apart from the process being considered and the spatial gradients in background concentrations are likely to be gentle. However, in these situations it is simpler to use monitoring data directly and assume that the spatial gradients are not significant.

A particular weakness of interpolation methods is that they do not make use of the additional information available from emission inventories to estimate background concentrations. An interpolation of rural annual mean NO<sub>2</sub> concentrations, for example, systematically underestimates concentrations in urban areas and vice versa. Methods such as co-kriging can be used to incorporate emission inventory information into interpolation methods on an empirical basis. However, the use of dispersion models or values from background maps has the benefit of treating the emissions within a model that attempts to provide a more realistic description of the atmosphere.

## 5.5 Background maps

Maps of background air pollutant concentrations, such as those provided by Netcen, are a useful source of estimates of background concentrations. These maps have been built up by combining the contributions to ambient concentrations from a number of different sources:

- ▶ *large point sources* – modelled explicitly using a dispersion model;
- ▶ *small point sources* – modelled using a generalised dispersion kernel approach;
- ▶ *area sources* – modelled using a dispersions kernel approach, calibrated using automatic measurements;
- ▶ *regional rural concentrations* – interpolated from rural measurements, corrected for local source contributions.

The maps currently available on the web ([www.airquality.co.uk/archive/laqm/tools.php](http://www.airquality.co.uk/archive/laqm/tools.php)) provide estimates of background concentrations in 2001. The methods used to derive these estimates are described by Stedman *et al.* (2002), with recent updates in 2003 and 2005 (Stedman *et al.*, 2003, 2005), but these maps are not currently available on-line. This is because the 2001 maps were provided for use by local authorities within the Local Air Quality management process and were published to coincide with the publication of the technical guidance document TG(03) (Defra, 2003). It is possible that updates will be provided on the web to coincide with future updates to the technical guidance.

The background maps provide estimates of concentration on a 1 km x 1 km grid for the whole of the UK. The maps are used for a number of different purposes, including:

- ▶ annual air-quality assessment required within the EU Framework and Daughter Directives;
- ▶ assessment of the achievement of AQS objectives;
- ▶ development of UK air-quality policy via the calculation of projections for future years.

Thus, an attempt has been made to represent all of the sources in the National Atmospheric Emissions Inventory (NAEI) within the modelling. An estimate of the contribution from regulated process emissions to ambient concentrations is included in these maps, as discussed in some detail in Section 3. There is therefore some risk of double counting the PC when using these mapped background estimates. One

alternative would be the provision of maps without the regulated PC. But the background for the assessment of one process should include contributions from all other processes and it is not practical to recalculate a unique background concentration for each process within this mapping work.

If there is a risk of significantly overestimating the PEC because of double counting the PC, a background concentration can be estimated by choosing values from the grid squares outside of the highest concentration within the process footprint. Care should be taken to select a background location of similar environment (urban, rural, etc.) to that of the process footprint.

If the background values for the location of the process footprint are used directly, the environment of the process footprint should be represented correctly within the mapped estimates.

The mapping process introduces additional uncertainties when compared with the direct use of automatic monitoring data. If available, monitoring data should be used in preference to mapped values.

## 5.6 Automatic monitoring data

### 5.6.1 Introduction

The use of automatic data to determine the background concentrations for regulatory assessments is recommended. The main reason not to use automatic data is if monitoring data are not available within an acceptable distance of the assessment location. A number of issues need to be considered when using automatic monitoring data:

#### **Site environment**

It is important to match the site environment with the footprint of the PC, as far as is reasonably practicable. You may need to use more than one site to represent the process footprint if the footprint includes a variety of areas, such as both rural and urban areas.

#### **Data quality and data capture**

The data quality and data capture issues raised in Section 4 are important when using automatic monitoring data.

#### **Distance**

Distances within about 10 km are likely to be acceptable and distances of up to about 50 km may also be acceptable in some circumstances. The suitability of a monitoring site for providing data appropriate for the assessment of background concentrations depends to a large extent on the presence or absence of other significant air pollution sources in the locality. This determines the extent of spatial gradients in concentrations. Gradients are typically greatest in urban areas for pollutants with significant traffic sources. In this instance, it may be more important to choose a background site for which the site environment matches that of the process footprint, rather than the closest site if the environment is a poor match.

#### **Double counting**

The risk of significant double counting of the PC is likely to be small if the PC is much less than the PEC. It may be more of an issue if the PC is larger, particularly if it is close to or above the EAL. In this case, consideration should be given to the use of pollution roses or modelling methods to avoid double counting the PC. An assessment of the PC at a range of automatic monitoring sites is provided in Section 3 of this report.

## 5.7 Automatic data plus pollution roses

### 5.7.1 Introduction

Monitoring data from sites close to industrial processes can still be used to provide estimates of background concentrations for regulatory assessments. The advantage of using sites close to the process location is that it avoids the potential of more distant sites providing a poor representation of the background concentration. If the PC is significant relative to the PEC or EAL, it may be necessary to take steps to ensure that the PC is not counted twice (see Section 3). Pollution roses provide one possible method to estimate the background concentration by the exclusion of hours in which the process made a significant contribution to the measured ambient concentration from the calculation of the annual mean.

The full data set of hourly average concentration measurements is required for pollution rose analysis, along with hourly wind direction and speed data from the nearest available meteorological station.

Ambient air-quality measurements in the vicinity of a process location will include a contribution from the emissions of the process. This is especially so if the monitoring sites are within the area of maximum likely impact of the footprint (within about 5 km for a source with a tall chimney, such as a power station, or closer for smaller chimneys).

### 5.7.2 Wind shear

Wind direction near to the ground often differs from that aloft. This effect is called wind shear and is caused by the frictional slowing of air near to the ground. Typical wind shear between 10 m and the height of power station plumes is likely to be some 10-30° (Laxen, 1996), and rather less than this for processes with shorter chimneys. Wind is rotated clockwise with greater height, so a wind direction of 180° measured at 10 m could correspond to a direction of 190° at a higher level. The effect of this phenomenon is that direction in a pollution rose based on ground level wind measurements is rotated anti-clockwise compared to the actual bearing of an elevated pollution source.

### 5.7.3 Choosing which wind directions are influenced by a process

Pollution roses should be examined and compared with the locations of pollutant sources before assigning particular directions to PCs. Where the PC is dominant, it is often relatively easy to assign directions to it by comparing the pollution rose with a map that shows the locations of the monitoring sites, or sites and the process release locations. Where the contribution does not stand out from the contribution of other

sources, the process directions should be assigned by examining the map and including the wind shear effect. Wind directions 10° either side of the expected directions should also be included.

Interpretation of the results of this type of analysis can be complicated by the presence of other significant emission sources in the area. If other major sources are in the same direction as the process, relative to the monitoring site, it is not possible to separate out the contributions from the process and the other sources. Estimates of background concentrations in this case are therefore underestimates, because the contribution from the other source are excluded from the calculation, along with the contribution from the process. If other major sources are in the vicinity, but not in the same direction, as the power station, the estimated background concentration will include the contribution from these sources.

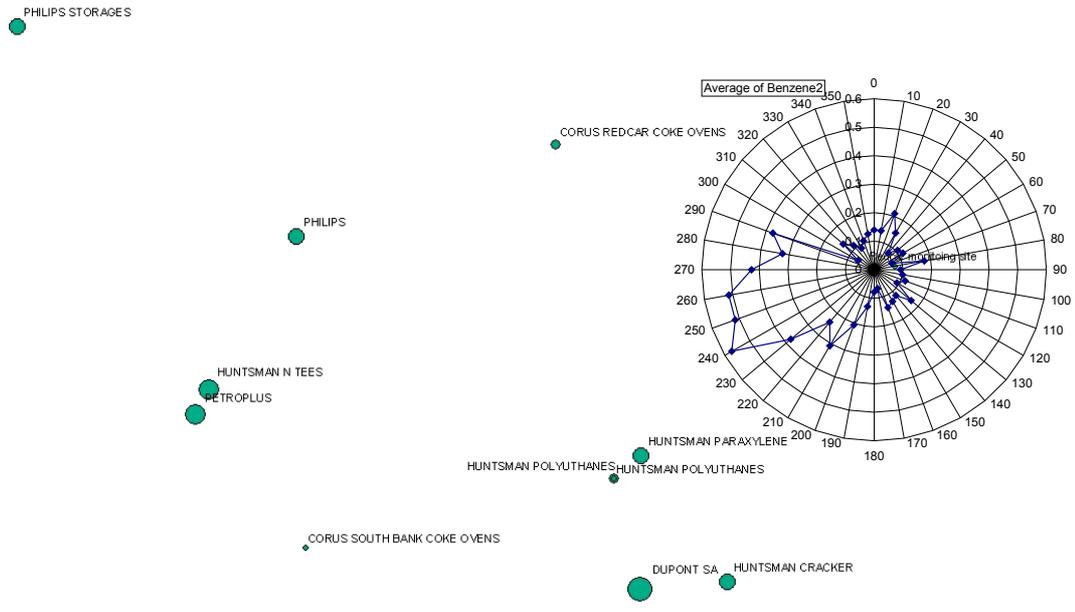
Annual mean ambient concentrations can be calculated from the full data sets, while estimated background annual means can be calculated using two different methods:

1. 'Background1' can be estimated by excluding from the calculation of the mean all hours with a wind direction from the process direction. This is the mean value if the wind never blew from the direction of the process.
2. 'Background2' can be estimated by replacing all hours with wind directions from the process direction by the mean concentration for the wind direction with the lowest value. This is the mean value, assuming that if the process was not there the air arriving from that direction would be as clean as the air that arrives from the direction with the lowest mean concentration. This, therefore, provides a reasonable lower limit for the background concentration.

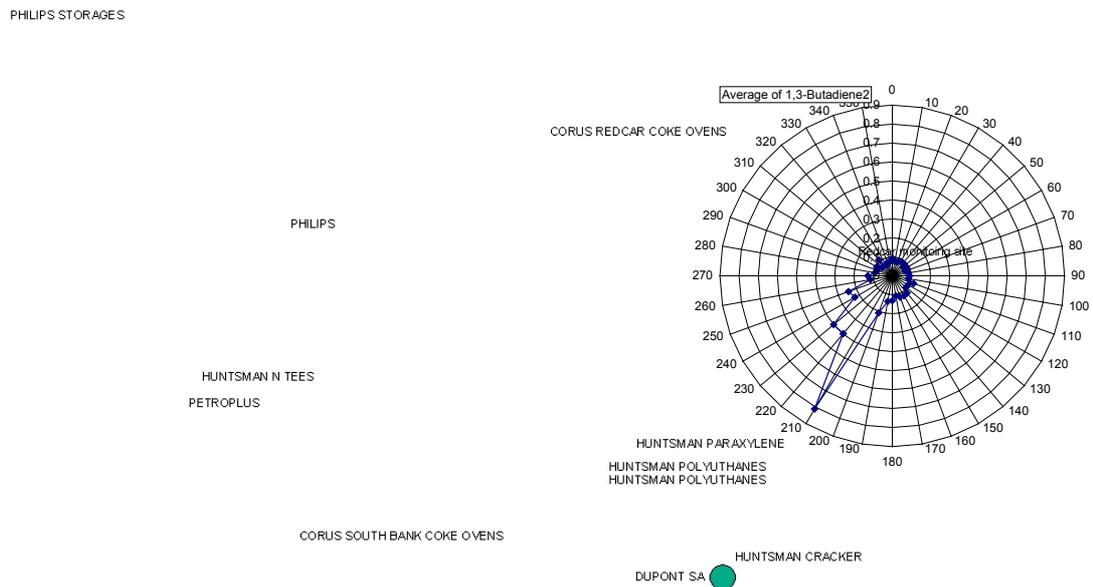
#### **5.7.4 Example**

*Figures 5.1 and 5.2* show examples of pollution roses for benzene and 1,3-butadiene for the Redcar automatic monitoring site for 2003. Examination of the pollution roses suggests that there are PCs from directions 190° to 290° for benzene and 190° to 260° for 1,3-butadiene. This analysis indicates that ambient concentrations at this site are strongly influenced by benzene emission from a number of industrial processes and that the influence on 1,3-butadiene concentrations is largely from just one source. The locations and magnitudes of the regulated process emissions close to the Redcar monitoring site are also shown in *Figures 5.1 and 5.2*.

The measured ambient and estimated background concentrations derived from this analysis are listed in *Table 5.2*.



**Figure 5.1 Pollution rose for benzene in 2003 at Redcar (ppb) and the locations of process benzene emissions**



**Figure 5.2 Pollution rose for 1,3-butadiene in 2003 at Redcar (ppb) and the locations of process 1,3-butadiene emissions**

**Table 5.2 Ambient and estimated background concentrations at Redcar in 2003 ( $\mu\text{g m}^{-3}$ )**

Benzene		1,3-butadiene	
Ambient	0.76	Ambient	0.55
Process direction	1.06	Process direction	0.87
Background 1	0.37	Background 1	0.21
Background 2	0.29	Background 2	0.17

## 5.8 Automatic data plus modelling

Automatic data plus modelling is the most sophisticated method used to estimate annual mean background concentrations and it has been adopted in the assessments carried out for the major coal-fired power stations in England and Wales. This method is appropriate where:

- ▶ automatic monitoring data are available from sites within the footprint of a process;
- ▶ the PC is significant or the ambient concentration is close to or above the EAL.

An estimate of the background concentration is calculated by subtracting the modelled PC from the measured ambient concentration. The PEC is calculated as the sum of this background and the modelled PC. At first glance, the reasoning behind this method seems circular and does not seem to go beyond that available from an ambient measurement. The modelled location of maximum process impact may not, however, coincide with the location of the monitoring site and, in such instances, the PEC will be greater than the measured ambient concentration at this location.

This method is particularly appropriate for locations with several significant process emissions in the vicinity, since it enables the PCs to be considered in isolation from the other processes. Monitoring-site environment may still be an important consideration in some locations. While one rural monitoring site may provide an adequate estimate of the background concentrations of  $\text{SO}_2$  close to power stations, a rural site would not be appropriate for estimating background  $\text{NO}_2$  concentrations for urban locations.

# 6 Methods to estimate background concentrations for short-term assessments

## 6.1 Introduction

A number of guidance documents have been prepared to advise on methods of carrying out air quality assessments required under the Air Quality Strategy. These include *Guidance for estimating the air quality impact of stationary sources* (Environment Agency, 1998), *Local Air Quality Management: Review and Assessment: Pollutant Specific Guidance* (DETR, 2000) and *Local Air Quality Management: Technical Guidance* (Defra, 2003b).

Further work was commissioned by the Environment Agency on the range of methods available to estimate background concentrations and combine these with PCs in typical regulatory situations (Abbott and Downing, 2000). An objective of the current project is to update and extend the range of sources, methods and background data available for such assessments, continuing to focus on typical regulatory situations where PCs dominate background concentrations in the short-term.

This section describes the latest methods available to estimate background concentrations of SO<sub>2</sub>, NO<sub>2</sub> and PM<sub>10</sub> appropriate for use within assessments against short-term EALs. It starts with some general comments about the relationships between annual mean and short-term PCs and annual mean and short-term ambient concentrations. Different methods available to estimate background concentrations and combine these with PCs are then discussed.

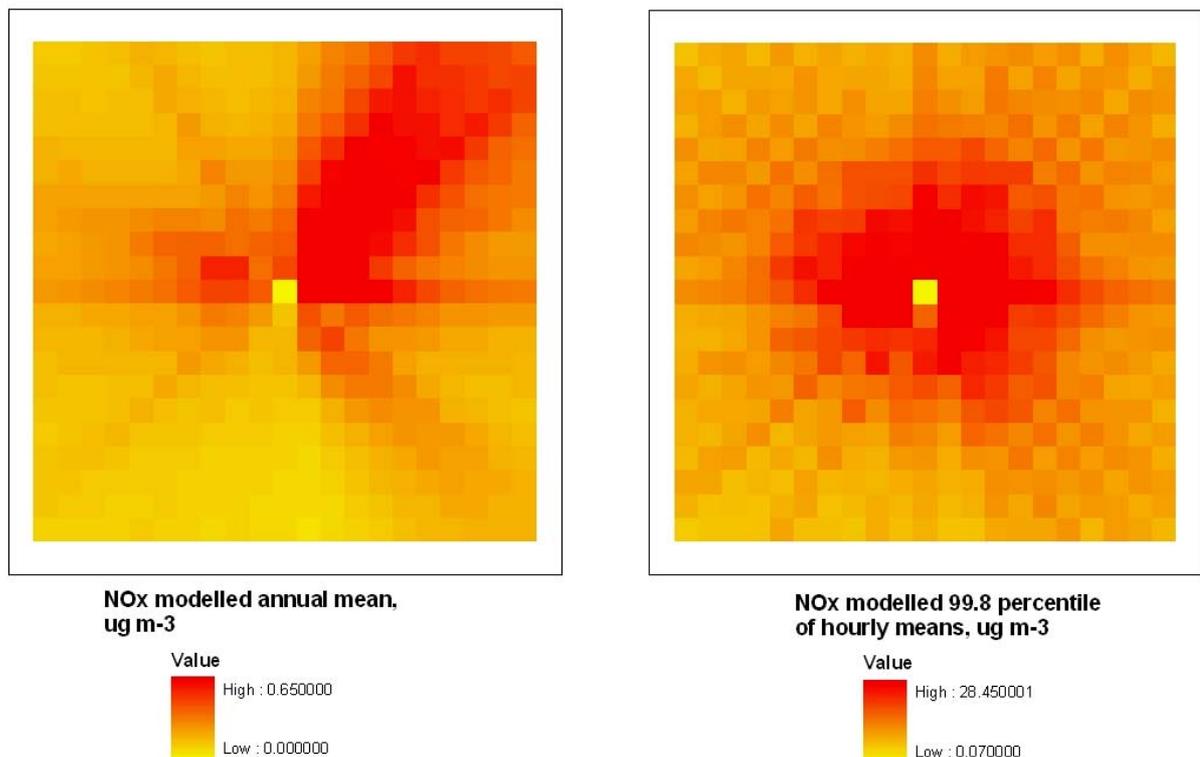
A key aspect of the assessment of background concentrations for comparison with short-term EALs is the choice of the appropriate background concentration metric. Ideally, both the PC and background concentrations should be assessed on an averaging period relevant to the EAL (for example, hourly), then added together and the required percentile concentrations or numbers of exceedances calculated. In many instances a full assessment of this type is not possible if, for example, only annual mean background concentrations are available.

It is generally not appropriate to add high percentile PCs and background concentrations together because this has no direct physical meaning and in any case the meteorological conditions that lead to high PCs often do not coincide with the conditions associated with high background concentrations. These issues, and the methods given in this section, are considered in more detail in the companion technical report [Abbott *et al.*, 2005]

## 6.2 Comparison of annual mean and short-term process contributions

### 6.2.1 NO<sub>x</sub>

The size and shape of the PC and location of the highest concentrations will be different for different averaging periods and metrics. The assessment of the PEC needs to focus on a combination of the areas of maximum impact and relevant exposure within the footprint. *Figure 6.1* shows example calculations of the modelled annual mean and 99.8 percentile of hourly mean concentrations of NO<sub>x</sub> from a source releasing about 500 g s<sup>-1</sup> from a stack about 180 m tall. Hourly sequential meteorological data for 2003 at Waddington are used in these example calculations and concentrations are calculated for a grid of 5 km x 5 km receptors.



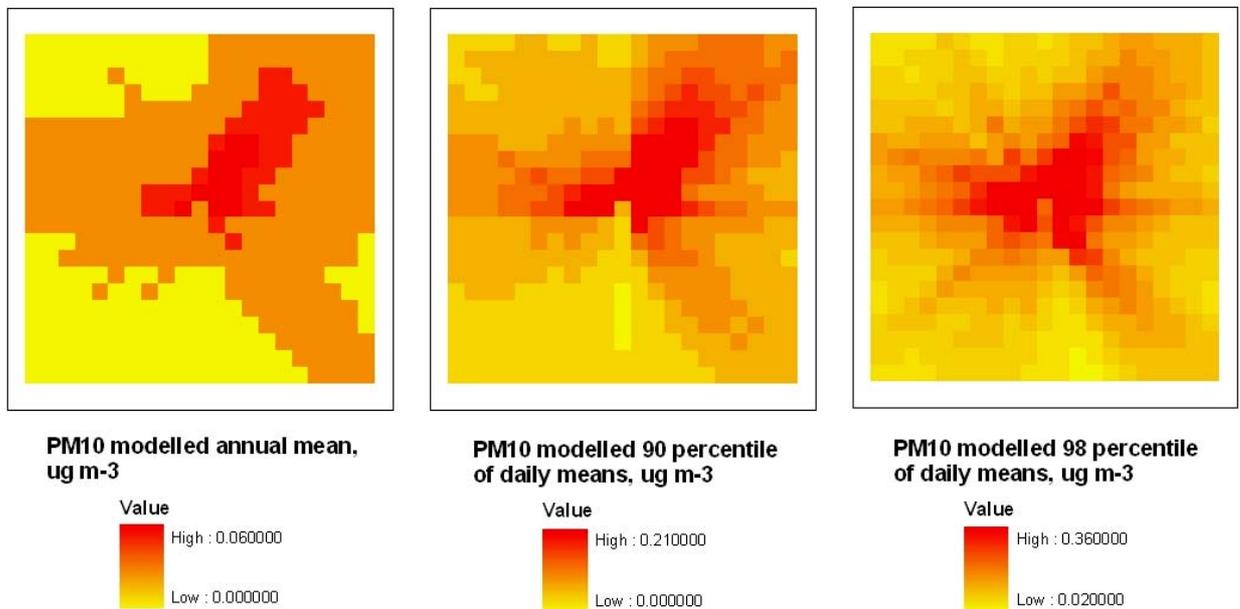
**Figure 6.1 Example of modelled NO<sub>x</sub> PCs**

The annual mean PC in *Figure 6.1* clearly shows the influence of the prevailing wind, with highest concentrations to the north east of the source. The modelled high percentile concentration, however, shows more of a circular pattern, with relatively similar concentrations in all directions and the maximum concentrations closer to the source. This is because the 99.8 percentile concentration at a given location will probably be for a different hour during the year than for other locations, so high concentrations are possible for all wind directions.

The assessment of background concentrations therefore needs to be appropriate for the relevant EAL and may be different for the assessment of annual mean and short-term concentrations. This may be an important consideration if, for example, there is an urban area to the south west of the source location examined here.

### 6.2.2 PM<sub>10</sub>

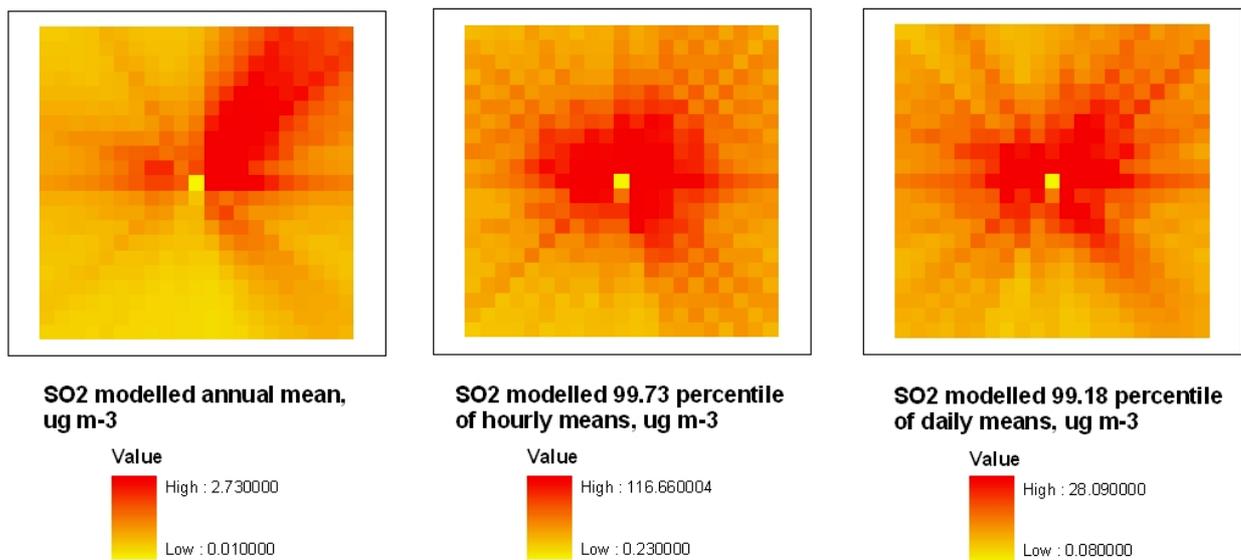
Figure 6.2 shows example calculations of the modelled annual mean and 90th and 98th percentiles of daily mean concentrations of PM<sub>10</sub> from a source that releases about 13 g s<sup>-1</sup> from a stack about 100 m tall. The annual mean PC clearly shows the influence of the prevailing wind, with highest concentrations to the north east of the source. The modelled 98th percentile shows a more symmetrical pattern of high concentrations, while the 90th percentile resembles the annual mean more closely than the 98th percentile.



**Figure 6.2 Example of modelled PM<sub>10</sub> PC**

### 6.2.3 SO<sub>2</sub>

Figure 6.3 shows example calculations of the modelled annual mean and 99.73 percentile of hourly mean and 99.18 percentile of daily mean concentrations of SO<sub>2</sub> from a source that releases about 5000 g s<sup>-1</sup> from a stack about 180 m tall. The annual mean PC clearly shows the influence of the prevailing wind, with highest concentrations to the north east of the source and the high percentile concentration showing a more circular pattern.



**Figure 6.3 Example of modelled SO<sub>2</sub> PC**

## 6.3 Comparison of annual mean and short-term ambient concentrations

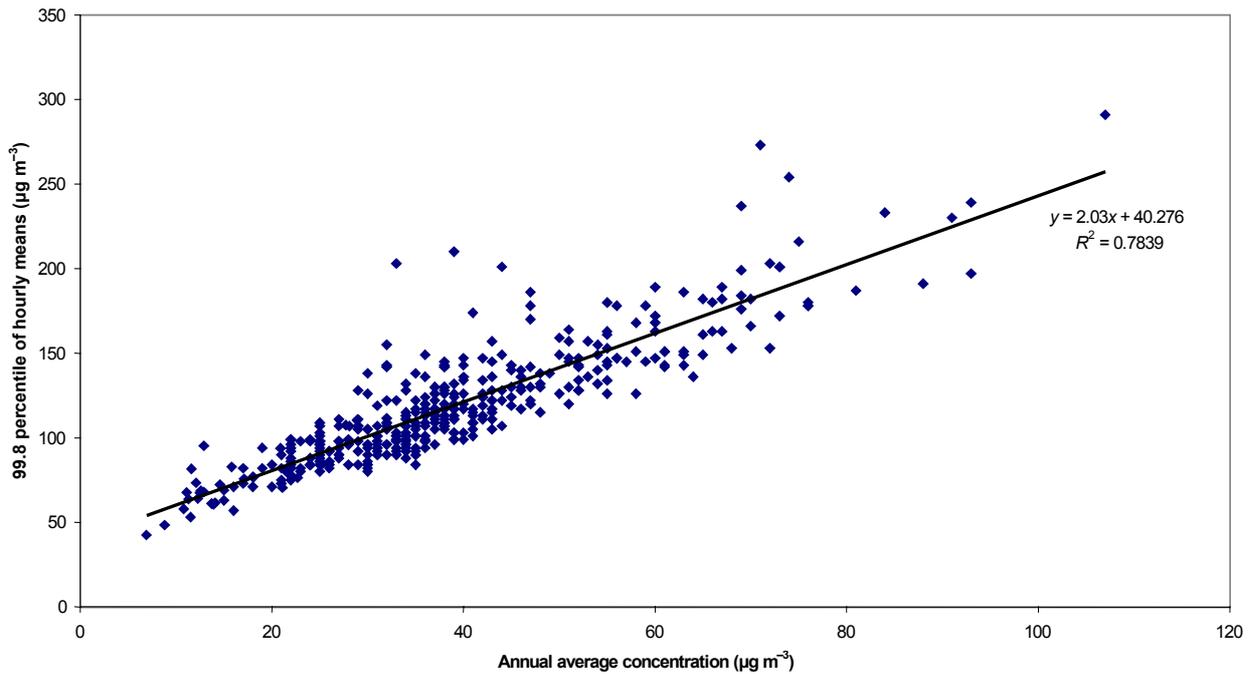
### 6.3.1 Introduction

The relationships between annual mean and high percentile ambient concentrations depend on the characteristics of the mix of different sources that contribute to ambient concentrations. For locations in which the dominant sources are releases from tall chimneys, the relationships between peak and mean concentrations are generally poor in comparison to locations in which emissions from the dominant sources are released closer to the ground.

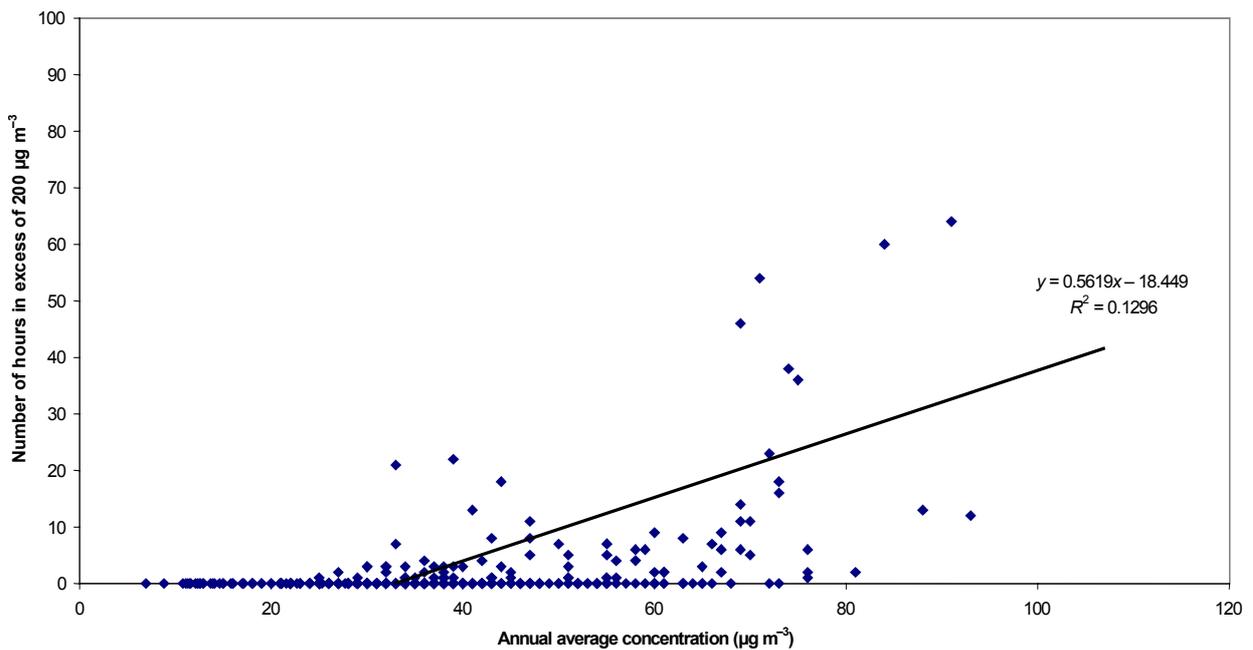
### 6.3.2 NO<sub>2</sub>

*Figure 6.4* shows a comparison of annual mean and 99.8 percentile of hourly mean NO<sub>2</sub> concentrations at national network sites in the UK. Road traffic and other low-level emissions are generally the dominant sources for NO<sub>x</sub> and NO<sub>2</sub>, which is reflected in the clear correlation between the annual mean and high percentile concentrations.

*Figure 6.5* shows that there is no clear relationship between the number of hours with concentrations above 200 µg m<sup>-3</sup> and the annual mean. This figure does, however, illustrate that the annual mean objective and limit value are almost always more stringent than the corresponding hourly objective and limit value.



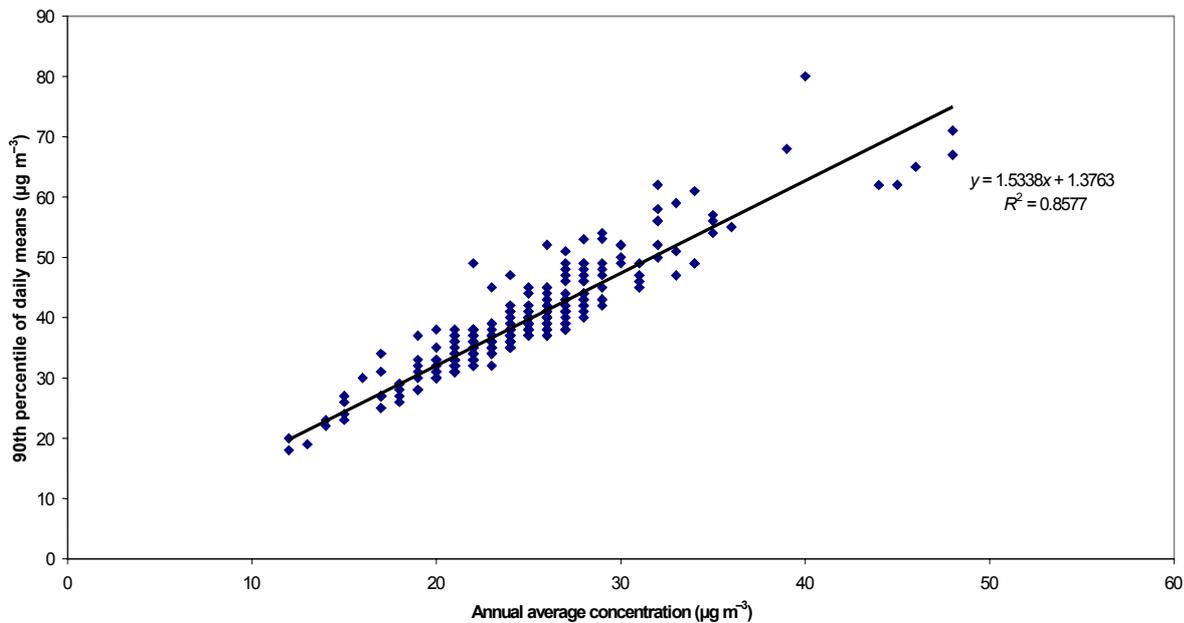
**Figure 6.4 Comparison of annual mean and 99.8 percentile NO<sub>2</sub> concentrations at national network sites 1999-2003**



**Figure 6.5 Comparison of annual mean and the number of hours with NO<sub>2</sub> concentrations above 200 µg m<sup>-3</sup> at national network sites 1999-2003**

### 6.3.3 PM<sub>10</sub>

Figures 6.6 and 6.7 show comparisons of annual mean and 90th and 98th percentiles of daily mean PM<sub>10</sub> concentrations at national network sites in the UK. The relationship between the 90th percentile and annual mean is stronger than that between the 98th percentile and annual mean, but both relationships are reasonably strong. This reflects the wide variety of contributions to ambient PM<sub>10</sub> concentrations on a daily and annual basis.



Fig

Figure 6.6 Comparison of annual mean and 90th percentile of daily mean PM<sub>10</sub> concentrations at national network sites 1999-2003 (µg m<sup>-3</sup>, TEOM x 1.3)

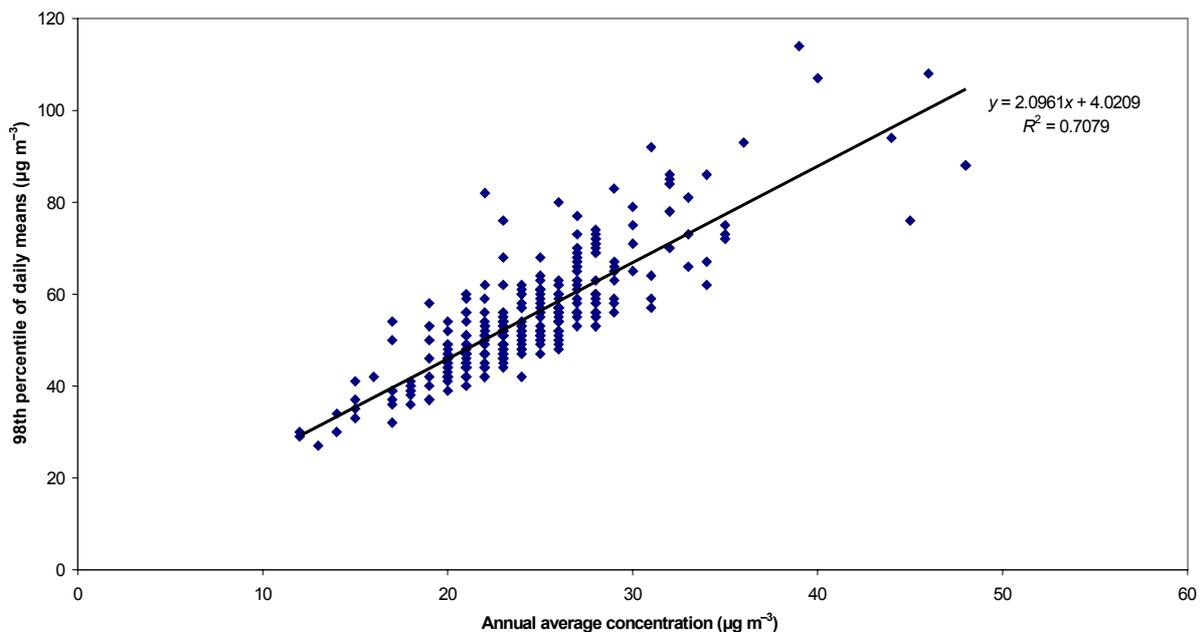
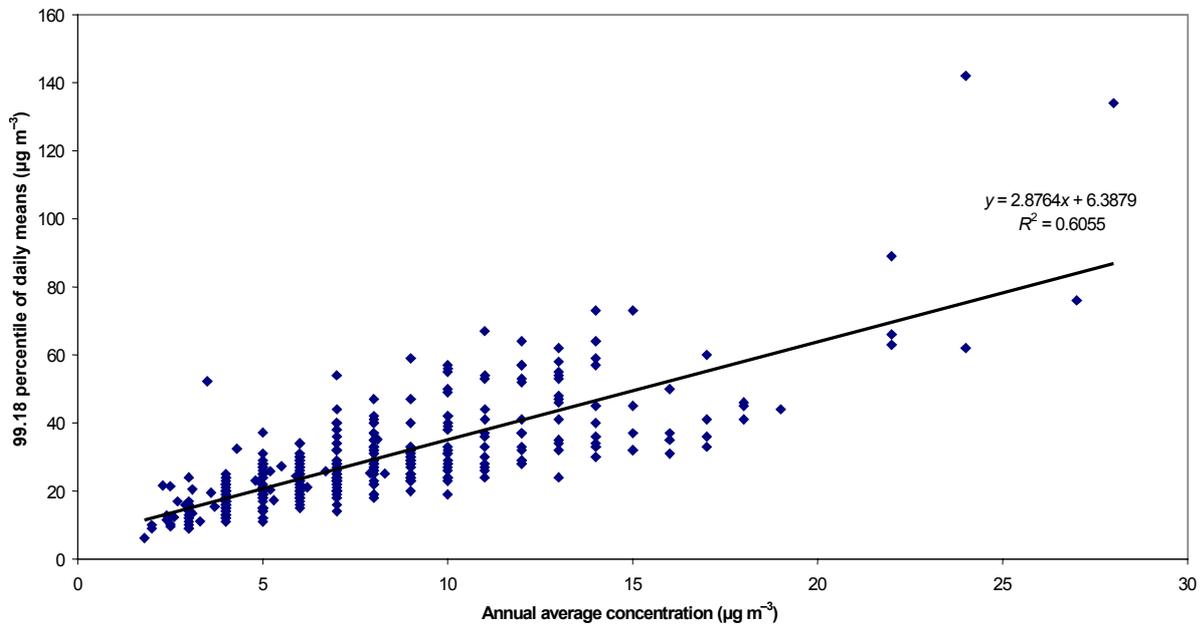


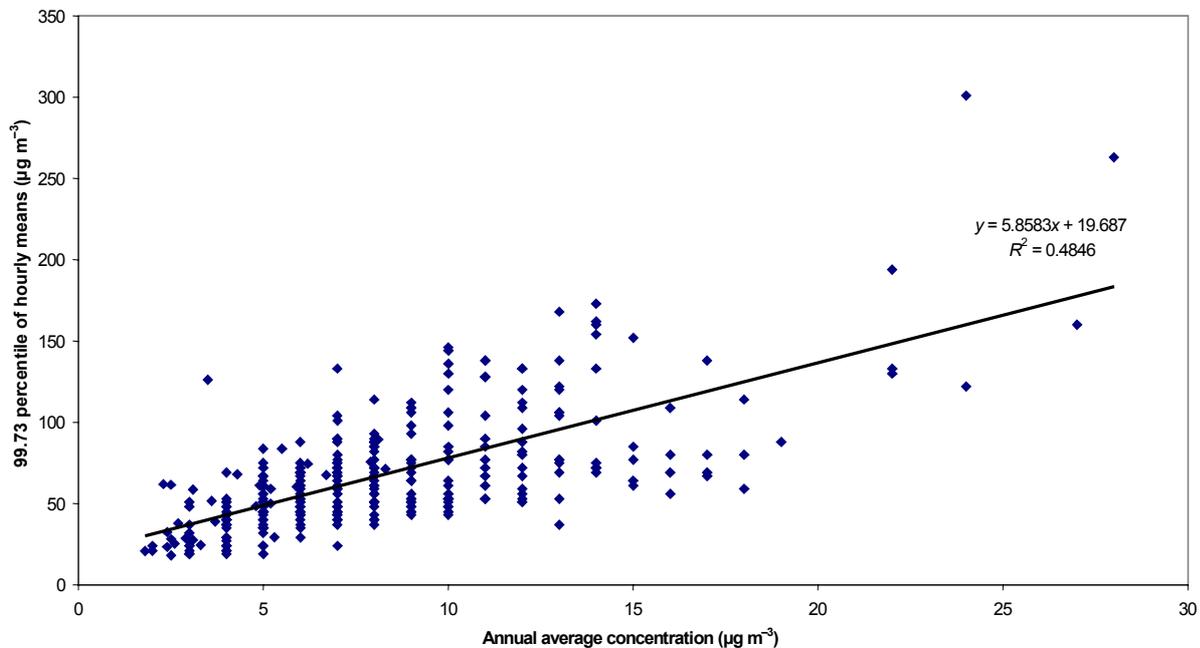
Figure 6.7 Comparison of annual mean and 98th percentile of daily mean PM<sub>10</sub> concentrations at national network sites 1999-2003 (µg m<sup>-3</sup>, TEOM x 1.3)

### 6.3.4 SO<sub>2</sub>

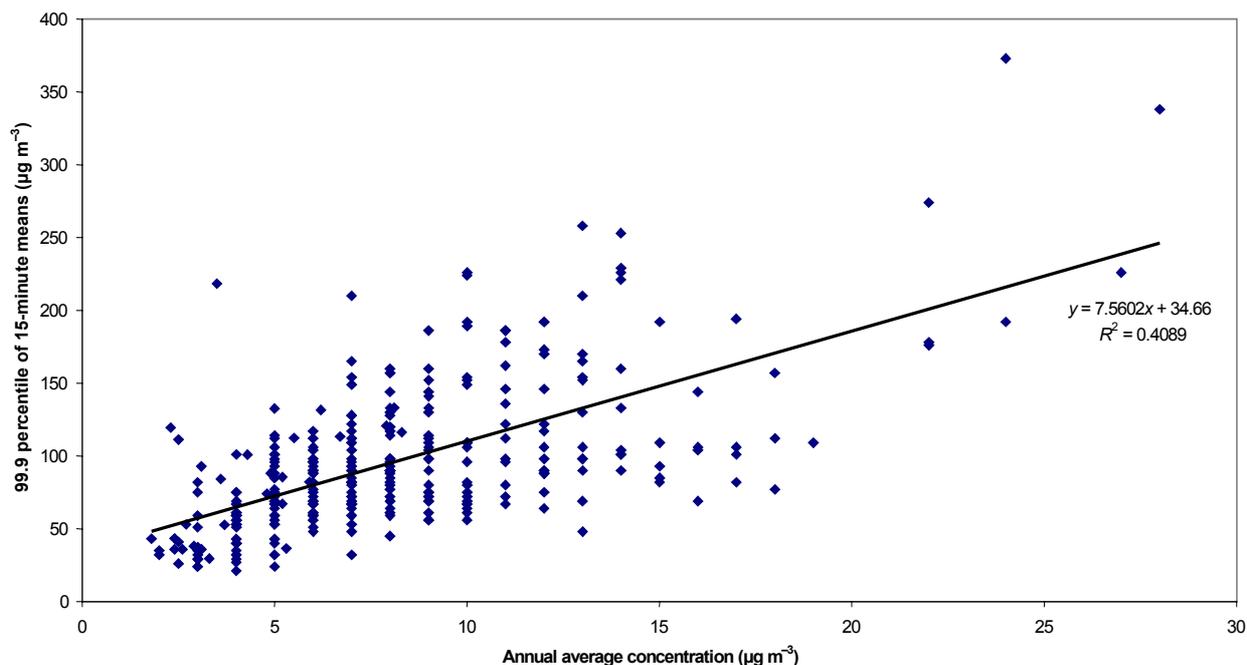
The situation is somewhat different for SO<sub>2</sub> because peak concentrations are generally strongly influenced by sources with tall chimneys. This is illustrated in *Figures 6.8, 6.9 and 6.10*. The relationship between annual mean and peak concentrations is weakest for the 15-minute mean concentrations.



**Figure 6.8 Comparison of annual mean and 99.18 percentile of daily mean SO<sub>2</sub> concentrations at national network sites 1999-2003**



**Figure 6.9 Comparison of annual mean and 99.73 percentile of hourly mean SO<sub>2</sub> concentrations at national network sites 1999-2003**



**Figure 6.10 Comparison of annual mean and 99.9 percentile of 15-minute mean SO<sub>2</sub> concentrations at national network sites 1999-2003**

### 6.3.4 Estimating percentiles from annual means

It is possible to estimate percentiles of background concentrations from annual means for use in short-term air quality assessments using the relationships illustrated above. The resulting percentile concentrations will only be approximate and must therefore be treated with caution, but they may be suitable for use in screening assessments where background is small compared to the PC and the PEC is a significantly lower than the EAL.

In such cases, automatic monitoring data from a nearby or an equivalent site environment should be selected and the factor describing the relationship between the desired percentile of short-term concentration and the annual mean should be derived. This factor should then be applied to the annual mean at the location of the assessment (identified from the sources of annual mean data described in Section 5) to estimate the percentile of background concentration required for the assessment. The robustness of the derived factor can and should wherever possible be improved by using multiple sources of data to derive the factor, as long as the location of each source site is representative of the study location. In these cases, linear regression should be used to derive the best-fit relationship between annual means and short-term concentration percentiles as in *Figures 6.4 - 6.10*.

If automatic monitoring data are available, they should be used in preference to this method.

## 6.4 Automatic data: the baseline method of adding process and background contributions on an hourly basis

The assessment of the PEC for short-term EALs typically involves the calculation of a high percentile concentration for comparison with the EAL. Both the PC and the background contributions to the total concentration vary from hour to hour. The most reliable method to calculate the PEC is therefore to add a background contribution to the PC on an hourly basis, either within the dispersion modelling exercise or within post processing. The percentile PEC can then be calculated directly from the hourly data.

This method is relatively computationally intensive and is therefore most appropriate for assessments that require a detailed assessment of the background. This is the case when the PEC is close to or above the EAL.

Double counting should be considered if modelling studies indicate a significant PC at the background measurement site location. Either pollution rose analysis or subtraction of the hourly modelled PC can be used to avoid double counting when compiling the data set of background concentrations.

## 6.5 Automatic data: alternative methods for adding process and background contributions

### 6.5.1 Introduction

Alternative methods for adding process and background contributions were tested and are discussed in some detail in the accompanying companion technical report (Abbott *et al.*, 2005). A summary of the key points is provided here for easy reference.

The preferred method to assess short-term percentile concentrations is to add the background concentration derived from monitoring data to the modelled contribution from the process on an hour-by-hour basis throughout the year, and then to calculate the percentile concentrations from the hourly total modelled concentrations. This is considered the 'baseline' method. However, this is not always easily accomplished and the effort involved in such an assessment may not be justified where there is little risk of air-quality objective limits being exceeded. Various methods have been suggested to enable the total percentile concentration to be calculated approximately from statistical estimators of the background concentrations and the source contributions to pollutant concentrations. These simple methods are particularly useful for screening purposes to identify whether there was a risk of exceedance of air-quality objective limits. Simple methods were investigated in earlier research for the Environment Agency (Abbott and Downing, 2000). The first objective of this work was to extend the range of sources, methods and background data.

Some initial investigation of the feasibility of the baseline hour-by-hour method was carried out. Inevitably, data were missing from the background monitoring and meteorological data. In addition, most dispersion models ignore hours in which wind speeds are low; however, these are the hours when the highest background concentrations often arise. Hour-by-hour addition of background and PCs and the calculation of percentile concentrations ignoring these hours may lead to some underestimation. In the accompanying report (Abbott *et al.*, 2005) the background concentrations for the hours with missing data were set equal to the previous hours' values. Similarly, meteorological data from the previous hour were used as a substitute for missing meteorological data or where wind speeds were low. Further work may be necessary to establish the most appropriate way to deal with missing data and calm conditions.

Dispersion models are commonly used to establish whether there is a risk of exceedance of air-quality objective limits in the vicinity of an industrial source. They are also used to predict the location and spatial extent of potential exceedances. Contour plots of predicted concentrations (isopleths) are often used to show their spatial variation. The second objective of the accompanying report was to ascertain whether the simple methods of calculating percentiles of PEC were able to predict the spatial variation in pollutant concentrations predicted by the baseline method. Contour plots were prepared that showed the spatial variation in predicted concentrations calculated using the various methods.

Simple methods to combine process and background contributions most closely resemble the baseline estimates when the background concentration is small compared to the PC. In practice, the simple methods are most useful when the background concentration is small compared to the relevant air-quality objective limits. The performance is worst when the PC and the background concentration are similar in magnitude. In addition, the performance of the simple methods is different for each pollutant. The following sections describe the performance of the simple methods compared to the baseline for SO<sub>2</sub>, NO<sub>x</sub> and PM<sub>10</sub>.

### 6.5.2 SO<sub>2</sub>

For SO<sub>2</sub>, the background concentration is generally small compared with the objective limits and the simple methods perform well. Two simple methods are available, both of which can be used to add source contributions,  $S$ , to background concentrations,  $A$ , to provide estimates of the total percentile concentrations,  $T$ , compared with baseline method. These are:

- i) The maximum twice annual mean method, in which

$$T_q = \max\{A_q + 2S_m, S_q + 2A_m\}$$

and  $q$  denotes the required percentile and  $m$  the annual mean.

- ii) The sum of squares method, in which

$$T_q = S_m + A_m + \sqrt{[(S_q - S_m)^2 + (A_q - A_m)^2]}$$

The methods are found to be effective for each of the Air Quality Strategy objectives for SO<sub>2</sub>:

- ▶ The 99.9 percentile of 15-minute means;
- ▶ The 99.73 percentile of one-hour means;
- ▶ The 99.18 percentile of 24-hour means.

Contour plots that show the spatial variation in predicted concentrations using the simple methods for SO<sub>2</sub> provide satisfactory estimates of the location and extent of possible exceedances of the objective limits.

The simple methods rely, to some extent, on the source contribution and the background concentration not being correlated. However, analysis of the Trent Valley air-quality monitoring data indicated that some correlation exists. It is uncertain whether the correlation arises artificially as a result of the methods used to separate the measured concentration into the process component and the background concentration component. Nevertheless, it is recommended that model predictions be confirmed using hour-by-hour addition of background concentrations when the predicted concentration using the simple methods exceeds 75 per cent of the objective limits.

### 6.5.3 NO<sub>2</sub>

For NO<sub>2</sub>, most of the simple methods provide a conservative assessment of the baseline predictions. It is therefore recommended that the modified technical guidance method be used for screening purposes:

$$T_q^{NO_2} = \min \left\{ A_q^{NO_2+O_3} + 0.05S_q^{NO_x}, \max \left[ S_q^{NO_x} + 2A_m^{NO_2}, A_q^{NO_2} + 2S_m^{NO_x} \right] \right\}$$

where the superscripts NO<sub>x</sub> and NO<sub>2</sub> refer to oxides of nitrogen and nitrogen dioxide, respectively. The superscript NO<sub>2</sub>+O<sub>3</sub> refers to the total oxidant concentration of ozone and NO<sub>2</sub> (as NO<sub>2</sub> equivalents).

This method provides conservative overestimates compared with the baseline method. Furthermore, the method assumes that nitric oxide released from the industrial source reacts instantaneously with the available ozone mixing with the discharge plume to form NO<sub>2</sub>. This assumption increases the degree of conservatism inherent in the method.

The simple methods are not able to provide useful predictions of the location of the maximum or of the possible extent of exceedances of the 99.79 percentile of hourly mean objective limits. Contour plots of the predicted 99.79 percentile NO<sub>2</sub> concentrations produced using the simple methods may be misleading.

#### 6.5.4 PM<sub>10</sub>

For PM<sub>10</sub>, the background concentration is often large compared with the air-quality objective, particularly for the provisional objective of 50 µg m<sup>-3</sup> as a 24-hour mean, not to be exceeded more than seven times in a year (the 98.08 percentile).

The simple methods (the maximum twice annual mean and sum of squares methods) provide reasonably good estimates of the maximum 98.08 percentile concentrations and are recommended for screening purposes. Hour-by-hour modelling should be considered when the predicted increase in 98.08 percentile concentration that will result from the process above the background concentration is more than some fraction (for example, 50 per cent) of the headroom between the background concentration and the objective limit.

The simple methods are not able to provide useful predictions of the location of the maximum or of the possible extent of exceedances of the 98.08 percentile objective limits. Contour plots of the predicted 98.08 percentile concentrations produced using the simple methods may be misleading.

The sum of squares method is recommended for screening against the current objective of 50 µg m<sup>-3</sup> as a 24-hour mean, not to be exceeded more than 35 times in a year (the 90.41 percentile). The maximum twice annual mean method is not applicable. However, the maximum annual mean method may be used:

$$T_q = \max\{A_q + S_m, S_q + A_m\}$$

Hour-by-hour modelling should be considered when the predicted increase in 90.41 percentile concentrations that will result from the process above the background concentration is more than some fraction (for example, 50 per cent) of the headroom between the background concentration and the objective limit.

Contour plots that show the spatial variation in the 90.41 percentile concentrations prepared using the simple methods will generally show the location and extent of potential exceedances of the objective.

## 6.6 What to do if automatic data are not available

If automatic monitoring data are not available, the method described in Section 6.3.4 can be used to estimate short-term background concentrations from other sources of background data, e.g. typical concentrations, indicative monitoring, interpolation and background maps, each of which typically only provide annual means.

The simple methods for combining background concentrations and PC described in section 6.5 can then be used to estimate the PEC.

# 7 Guidance

## 7.1 Introduction

This section provides guidance on the selection of background concentrations for use within regulatory assessments. It includes the following subsections:

- ▶ general approach;
- ▶ checklists to assist in decision making;
- ▶ advice on what statistics to collect for each pollutant.

## 7.2 General approach

The general approach is that the level of detail required in the assessment of background concentrations should be appropriate to each assessment. Thus, this approach should take into account the:

- ▶ risk of exceeding air-quality objectives;
- ▶ relative importance of the process and background contribution to the risk of exceeding objectives.

Some examples of the importance of the assessment of background concentrations are provided in *Table 1.1*, which is repeated here as *Table 7.1* for easy reference. This table has been colour-coded to show the level of detail required for the assessment of background concentrations (red = most detailed, green = least detailed).

**Table 7.1 Possible results of an air-quality assessment and the level of detail required for the assessment of background concentrations**

PEC relative to EAL	PC relative to background	Notes
PEC > EAL, PC > EAL	PC >> background	PC above EAL, so there is an air-quality issue irrespective of the choice of background
PEC > EAL	PC >> background	If PC is below EAL, selection of background is important
PEC > EAL	PC similar to background	Selection of background is important
PEC > EAL	PC << background	PEC is dominated by background, so selection of background is important
PEC < EAL	PC >> background	PEC is dominated by PC, so selection of background is less important
PEC < EAL	PC similar to background	Selection of background is important, but less important than if PEC > EAL
PEC < EAL	PC << background	Selection of background is important, but less important than if PEC > EAL

The various sources of background concentrations are described and discussed in Sections 5 and 6. The recommended approach is that the more detailed assessments of background concentrations are generally only required if the PEC > EAL.

The use of automatic monitoring data is highly recommended. Automatic monitoring data may be available from the AURN, other regional networks, Local Authorities or process operators. Information on the importance of understanding site environments and quality assurance is provided in Section 4. If the PEC < EAL, it is unlikely that double counting will need to be accounted for. If the PC < 10 per cent of EAL, double counting is unlikely to be a problem unless the PEC > EAL. The best methods to remove double counting are pollution roses and modelling of the PC, as described in Section 5.

If automatic monitoring data are not available, either typical values or estimates from background maps can be used. Values from the background maps should be used if they are higher than the typical values. Double counting of the PC may be a problem when using the background maps, particularly for SO<sub>2</sub>. If automatic monitoring data are unavailable and the PEC is consistently estimated to be > EAL, a monitoring programme should be considered if the background is thought to be a significant component of the PEC and it is not very well defined.

### 7.2.1 General checklists (high, medium and low importance)

Where a range of importance is given, this suggests that the importance of the criteria will vary considerably from place to place.

#### *What is the likelihood of exceeding objectives?*

<i>Pollutant</i>	<i>Exceedance</i>
SO <sub>2</sub>	Low–high
Benzene	Low–medium
NO <sub>2</sub>	High
PM <sub>10</sub>	High
BaP	Low–high

The likelihood of exceeding SO<sub>2</sub> objectives is highly variable and typically dependent on process emissions or domestic coal use. The likelihood of exceeding benzene objectives is less and typically dependent on process emissions or traffic emissions. The likelihood of exceeding NO<sub>2</sub> objectives is high and typically dominated by road traffic emissions. The likelihood of exceeding PM<sub>10</sub> objectives is also high and contributions can be from a range of sources, including process emissions and traffic and regional background concentrations. The likelihood of exceeding BaP objectives is highly variable and typically dependent on process emissions or domestic coal use.

**How important is it to match the environment of the process and the background assessment (urban, rural, etc.)?**

<i>Pollutant</i>	<i>Environment</i>
SO <sub>2</sub>	Low–medium
Benzene	High
NO <sub>2</sub>	High
PM <sub>10</sub>	Medium
BaP	Medium

For SO<sub>2</sub>, this is only very important in areas with domestic coal use. There are significant road traffic sources of NO<sub>2</sub> and benzene, so it is very important to match the process and background assessment environments for these pollutants. It is less critical for PM<sub>10</sub>. Urban concentrations of BaP may be much higher in areas with domestic coal use.

**How important is it to make sure that the PC is not included in the background concentration?**

<i>Pollutant</i>	<i>Process contribution</i>
SO <sub>2</sub>	High
Benzene	Medium
NO <sub>2</sub>	Low
PM <sub>10</sub>	Low
BaP	Medium

See Section 3 for a discussion.

**How important is long-range transport?**

<i>Pollutant</i>	<i>Long-range transport</i>
SO <sub>2</sub>	Low
Benzene	Low
NO <sub>2</sub>	Low
PM <sub>10</sub>	High
BaP	Low

**How important is chemistry?**

<i>Pollutant</i>	<i>Chemistry</i>
SO <sub>2</sub>	Low
Benzene	Low
NO <sub>2</sub>	Medium
PM <sub>10</sub>	Medium
BaP	Low

## 7.3 What statistics to collect

### 7.3.1 SO<sub>2</sub>

The most important statistics to collect for the annual mean for SO<sub>2</sub> are the annual mean background concentration for assessment against the annual mean EAL (the ecosystem limit value and objective) and statistics appropriate for use within the

assessment against the short-term EALs (the 15-minute objective is generally the most stringent, see *Table 2.1*).

The most reliable method for calculating the PEC is to add a background contribution to the PC on an hourly basis. The percentile PEC can then be calculated directly from the hourly data. Simpler methods of combining the process and background concentrations can also be used in situations for which a less detailed assessment of the background is appropriate or hourly data are not available. Either the maximum twice annual mean method or the sum of squares method can be used.

### 7.3.2 NO<sub>x</sub>/NO<sub>2</sub>

The annual mean EAL is generally more stringent than the hourly EAL for NO<sub>2</sub>, so the assessment of background concentrations for NO<sub>2</sub> can often be limited to an assessment of annual mean concentrations. There is also an EAL for annual mean NO<sub>x</sub> concentrations for the protection of vegetation, so an assessment of annual mean background NO<sub>x</sub> concentrations may also be required. There are a number of possible methods to combine the process and background contributions to higher percentile hourly NO<sub>2</sub> concentrations for comparison with the one-hour EAL, if this assessment is required. These are described in detail in an accompanying technical report (Abbott *et al.*, 2005). The recommended method is the modified technical guidance method.

### 7.3.3 PM<sub>10</sub>

Assessments for PM<sub>10</sub> can be carried out for comparison with both annual mean and 24-hour mean EALs (see *Table 2.1*). Background concentrations can be combined with PC on an hourly or daily basis for comparison with the 24-hour mean EALs.

Simpler methods to combine the process and background concentrations can also be used in situations in which a less detailed assessment of the background is appropriate or hourly or daily data are not available. The maximum twice annual mean method and the sum of squares method can provide reasonably good estimates of the maximum 98.08 percentile concentrations for comparison with the 2010 24-hour EAL (50 µg m<sup>-3</sup> as a 24-hour mean, not to be exceeded more than seven times a year) and are therefore recommended for screening purposes.

The sum of squares method is recommended for screening against the current EAL of 50 µg m<sup>-3</sup> as a 24-hour mean, not to be exceeded more than 35 times in a year (the 90.41 percentile). The maximum twice annual mean method is not applicable, but the maximum annual mean method may be used.

The measurement of concentrations of particulate matter in ambient air is not straightforward. A variety of techniques to measure mass concentrations are available, but the complex nature of particulate matter, means that the method selected can significantly influence the result. It is therefore important to know the monitoring method used to measure PM<sub>10</sub> and to check whether any scaling factors have been applied to the concentrations.

### 7.3.4 Benzene

The assessment of background concentrations for benzene is generally confined to an assessment of annual mean concentrations. Benzene concentrations are,

however, measured at far fewer sites than are some of the other air pollutants. Automatic pumped tube measurements are recommended for benzene.

### **7.3.5 BaP**

The assessment of background concentrations for BaP is confined to an assessment of annual mean concentrations. BaP concentrations are not measured at many sites in the UK and it is therefore less likely that measurement data will be available for this pollutant.

## 8 References

Abbott J and Downing C, 2000 The addition of background concentrations to modelled contributions from discharge stacks, Technical Report P361. *Bristol: Environment Agency.*

Abbott J. A., Stedman J. and Bower J., 2005 Review of background air-quality data and methods to combine these with process contributions: technical modelling aspects. *Bristol: Environment Agency.*

Defra 2003 Local Air Quality Management: Technical Guidance, LAQM.TG(03). *London: Department for Environment, Food and Rural Affairs.*

DETR 2000 Local Air Quality Management: Review and Assessment: Pollutant Specific Guidance, LAQM.TG4(00). *London: Department of the Environment Transport and the Regions.*

Laxen D., 1996 Generating emissions? Studies of the local impact of gaseous power stations emissions. *Swindon: National Power plc.*

Stedman J. R., Bush T. J. and Vincent K. J., 2002 UK air quality modelling for annual reporting 2001 on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC. Report AEAT/ENV/R/1221. *Harwell: AEA Technology, National Environmental Technology Centre.*

Stedman J. R., Bush T. J., Vincent K. J. and Baggott S., 2003 UK air quality modelling for annual reporting 2002 on ambient air quality assessment under Council Directives 96/62/EC and 1999/30/EC. Report AEAT/ENV/R/1564. *Harwell: AEA Technology, National Environmental Technology Centre.*

Stedman J. R., Bush T. J., Vincent K. J., Kent A. J., Grice S. and Abbott J., 2005 UK air quality modelling for annual reporting 2003 on ambient air quality assessment under Council Directives 96/62/EC, 1999/30/EC and 2000/69/EC. Report AEAT/ENV/R/1790. *Harwell: AEA Technology, National Environmental Technology Centre*

Targa J., Xiao X., Derwent R. G., Goodwin J. and Bower J., 2005 UK air pollutants: key facts and monitoring data. *Bristol: Environment Agency.*

# Appendix A: Definition of site classes

## **Kerbside (U1)**

A site sampling within 1 m of the edge of a busy road.

Source influences	<i>Local traffic</i>
Examples of objectives	<i>Identifying vehicle pollution black spots</i> <i>Assessing worst-case scenarios</i> <i>Evaluating impacts of vehicle emission control technologies</i> <i>Determining impacts of traffic planning/calming schemes</i>

## **Roadside (U2)**

A site sampling between 1 m of the kerbside of a busy road and the back of the pavement. Typically this will be within 5 m of the road, but could be up to 15 m.

Source influences	<i>Local traffic.</i>
Examples of objectives:	<i>Assessing worst-case population exposure</i> <i>Evaluating impacts of vehicle-emission controls</i> <i>Determining impacts of traffic planning and/or calming schemes.</i>

## **Urban centre (U3)**

A non-kerbside site, located in an area representative of typical population exposure in town or city centres (for example, pedestrian precincts and shopping areas). This is likely to be strongly influenced by vehicle emissions, as well as other general urban sources of pollution. Sampling at or near breathing-zone heights will be applicable.

Source influences	<i>Vehicle, commercial, space heating</i>
Examples of objectives	<i>Identification of long-term urban trends</i>

## **Urban background (U4)**

An urban location distant from sources and therefore broadly representative of city-wide background conditions (for example, elevated locations, parks and urban residential areas).

Source influences	<i>Vehicle, commercial, space heating</i>
Examples of objectives	<i>Trend analysis</i> <i>Urban planning</i> <i>Traffic and land-use planning</i>

### **Urban industrial (U5)**

An area in which industrial sources make an important contribution to the total pollution burden.

Source influences:	<i>Industrial, motor vehicles</i>
Examples of objectives	<i>Assessing local impacts on health and amenity Process optimisation Source attribution and/or identification Providing model input data Model development and/or validation Local planning and plant authorisation</i>

### **Suburban (SU)**

A location type situated in a residential area on the outskirts of a town or city.

Source influences	<i>Traffic, commercial, space heating, regional transport, urban plume downwind of a city</i>
Examples of objectives	<i>Traffic and land-use planning Investigating urban plumes</i>

### **Rural (R1)**

An open country location in an area of low population density, as far as possible from roads, and populated and industrial areas.

Source influences	<i>Regional long-range transport, urban plume</i>
Examples of objectives	<i>Ecosystem impact studies Assessing compliance with critical loads and levels for crops and vegetation Investigating regional and long-range transport Identification of ozone 'hotspots'.</i>

### **Remote (R2)**

A site in open country, located in an isolated rural area, experiencing regional background pollutant concentrations for much of the time.

Source influences	<i>Regional and/or hemispheric background</i>
Examples of objectives	<i>Assessing 'unpolluted' global or hemispheric background conditions Long-range transport studies Long-term baseline trend analysis</i>

### **Special (Sp)**

A special source-oriented category that covers monitoring studies undertaken in relation to specific emission sources such as power stations, petrol stations, car parks or airports.

# Appendix B: Setting up a monitoring campaign

We here summarise some of the main issues to be considered in the establishment of an ambient air-quality monitoring campaign from scratch. This appendix should be read in conjunction with Section 4.

## Identifying relevant locations

To obtain useful air-quality monitoring data, the measurements made must be representative of the study area of interest. To achieve this, it is essential to choose the right site(s) for the monitoring equipment. A number of considerations need to be taken into account and it is worth investing reasonable effort in surveying possible sites before making a final choice. The approach taken to identify appropriate monitoring locations should be fully documented in the final report.

For public exposure studies, the sites should be located where people are likely to be exposed over the relevant time period for each pollutant in the Air Quality Strategy, or at least in a location representative of nearby exposure (for example, the same distance from a section of road as the façade of nearby residential properties). For a background-monitoring site, the location should be as far away from likely sources of pollution as possible.

The site selection process must take into account the spatial distribution and variability of gaseous pollutants. For example, concentrations of primary traffic pollutants, such as CO, are highest at roadside locations, whereas SO<sub>2</sub> concentrations may be highest at urban background or rural locations as a result of emissions from a point source. For this reason, it is usually not possible to optimise measurements for all pollutants at any one location, depending on the location of large point sources. In such circumstances, some degree of compromise may be required or several sites be employed to monitor individual pollutants.

The initial step in the process is to determine the likely distribution of pollutant concentrations around the area of interest. Whether the objective is to monitor in 'hot-spots' or background locations, this step helps to refine the selection of suitable locations.

The following information can be used when screening for potential areas for monitoring.

*Existing air-quality data:* National government, regulators, process operators and local authorities currently undertake a range of monitoring activities. Local data may be available to help assess future monitoring requirements. If monitoring has already been carried out in the area of interest, the data from previous studies may prove of use in targeting problem areas. Comprehensive monitoring of air quality is carried out on a national scale by the Department for Environment, Food and Rural Affairs (Defra), the Scottish Executive, the Welsh Assembly Government and the DoE Northern Ireland. Many of the sites have accumulated considerable historical data

sets. All data are freely available to anyone wishing to use this resource to assist in the appraisal of air quality in their area. Data from the networks can be obtained from a variety of sources:

- ▶ Air Quality Archive, <http://www.airquality.co.uk/>;
- ▶ National Atmospheric Emissions Inventory (NAEI), <http://www.naei.org.uk/>;
- ▶ Defra Air Quality Pages, <http://www.defra.gov.uk/environment/index.htm>.

Examples of the application of existing monitoring data include:

- ▶ use of data from nearby national network sites or neighbouring local authority sites to verify data obtained from short-term or simple monitoring exercises;
- ▶ estimating concentrations of pollutants with short-term averaging periods (for example, the use of daily mean SO<sub>2</sub> concentrations as an estimate of exceedances per year of 15-minute means).

*Modelling:* The results of dispersion modelling simulations can be used to predict pollutant dispersion and deposition patterns, and thereby help to identify areas in which concentrations may be low or pollutant problems may occur. To be of real use, reliable emissions and meteorological data are needed, together with an appropriate model. The model should be validated against data measured in the location of its application.

*Sources and emissions:* Compilations of emission data help to identify the most and/or least polluted areas. If a full emissions inventory is not available, surrogate statistics such as population density, location of industrial sources, traffic flows and fuel consumption may help to estimate the likely distribution of pollution. In this context:

- ▶ details of industrial processes authorised by the Environment Agency can be found on the Environment Agency web site, <http://www.environment-agency.gov.uk/> under 'What's in your backyard?';
- ▶ details of industrial processes in Scotland can be obtained from the Scottish Environmental Protection Agency (SEPA), <http://www.sepa.org.uk/>;
- ▶ Details of industrial processes in Northern Ireland can be obtained from the Environment and Heritage Service (EHS), <http://www.ehsni.gov.uk/default.asp>.

*Meteorology and topography:* The prevailing weather conditions and local topography strongly influence the dispersion of air pollutants or, in the case of secondary pollutants, affect their production in the atmosphere. Meteorological measurements can be made on-site, or data purchased from the authorised agencies.

*Other information:* Population and land-use information may be used to target locations representative of both baseline and worst-case exposure.

## Local siting criteria

Local siting is often difficult for automatic sites when taking into account factors such as visual impact and obtaining planning permission. However, to ensure meaningful comparisons of data between different areas, sites should be classified according to

the scheme given in Appendix A. In selecting site locations, recognised siting criteria should be employed as far as possible (see *Table 4.1* in the main text).

Details of site type and distance of nearby sources should be provided whenever results are reported.

## **Site numbers**

Monitoring is normally undertaken to assess pollutant behaviour in both space and time. A good programme design should therefore seek to optimise both spatial and temporal coverage, within available resource constraints.

The number and distribution of monitoring sites and samplers required to monitor air quality depends on both the spatial variability of the pollutants being measured and the required data usage. In general, automatic monitoring will only need to be carried out at one or two strategically located sites. This monitoring can be supported by diffusive or other simple samplers distributed over a wide area around the automatic site. It is recommended that diffusion tubes are co-located with the automatic monitors to estimate any bias in the diffusion tube measurements. The most important locations are those expected to be 'hot-spots', or those intended to provide background reference concentrations.

## **Screening surveys**

Wide-scale screening using simple monitoring techniques may be undertaken as an initial step to help identify if further monitoring is needed, or to assess the best location for detailed monitoring. Measurement methods, such as passive samplers, although fundamentally limited in their time resolution, are useful for a variety of area-screening, exposure assessment or network design functions. Site numbers and distribution should be selected so as to maximise information on the spatial distribution of pollutant concentrations.

The sites selected may need to target a number of locations optimised for source-impact monitoring, population exposure and rural background concentrations. Depending on the pollutants under assessment, data from a wide variety of location types may be necessary to build up a reasonably complete picture of ambient exposure patterns. The general criteria given in *Table 4.1* in the main text should be applied to the siting of individual samplers.

## **Use of mobile monitoring stations**

Automatic monitoring instruments may be installed in a mobile vehicle or other portable monitoring facility and deployed for short-term monitoring campaigns (lasting a few days or weeks) at a range of locations. The main application for mobile monitoring is for screening studies and to locate 'hot-spots'.

This type of study is particularly effective when carried out in conjunction with permanent fixed-site automatic monitoring studies. In practice, it can be difficult to move the mobile station to a range of locations for short periods unless the necessary services (for example, electricity and telephone) are in place. The data

require careful interpretation since very short-term monitoring can give a poor representation of longer-term averages.

### **Use of portable monitors**

To help select suitable monitoring locations, portable hand-held monitors can be used to obtain a 'snapshot' of pollution concentrations over a wide area. These are particularly useful for estimating impacts at sites of likely high concentration (for example, kerbsides and industrial point sources). Such monitors can be linked to global positioning and geographical information systems (GPS and GIS) to provide further enhanced information.

### **Detailed monitoring**

If screening surveys indicate that further detailed monitoring is required, measurement technologies must be selected that are capable of time resolution consistent with the pollutant averaging times specified in the Air Quality Strategy objectives.

Continuously operating automatic analysers may be used to make assessments against short- or long-term objectives. Well-recognised semi-automatic methods, such as bubbler-type smoke/SO<sub>2</sub> samplers, are perfectly adequate for obtaining daily concentration data for SO<sub>2</sub>, which will give a good general indication of shorter term concentrations (for example, 15-minute averages), but cannot directly demonstrate compliance with this objective.

Screening surveys should provide sufficient information to select a monitoring site for subsequent detailed studies using automatic monitors.

In addition to the siting criteria listed in *Table 4.1*, a variety of practical considerations also apply when selecting monitoring sites for automatic stations.

- ▶ it should be practical for power and telephone connections to be made;
- ▶ the site should be accessible for a vehicle to deliver the housing;
- ▶ it should be reasonably easy for gas cylinders to be delivered close to the site and transferred to the housing without difficulty;
- ▶ there should be easy access to the site at all times;
- ▶ the site should be in an area in which the risks of vandalism are minimal;
- ▶ Account will need to be taken of visual impact and opportunities to 'hide' the housing using pre-existing structures.

The analysers can be housed in a free-standing enclosure or in a suitable building. In either case, the inlet manifold should be positioned so that any buildings or structures do not impede the free flow of air around the sampling inlet. The housing should use air conditioning, or other means, to maintain a temperature of approximately 20±5°C.

### **Quality Assurance and Quality Control**

Please refer to the main text and the following documents for advice on QA/QC procedures for air pollution monitoring:

- ▶ UK Automatic Network Site Operator's Manual, <http://www.aeat.co.uk/netcen/airqual/reports/lsoman/lsoman.html>.
- ▶ UK NO<sub>2</sub> Diffusion Tube Network Instruction Manual, <http://www.airquality.co.uk/reports/no2man/no2man.html>
- ▶ UK Smoke and Sulphur Dioxide Network Instruction Manual, <http://www.aeat.co.uk/netcen/airqual/reports/smkmman/shead.html>

## **Data capture**

When considering setting up a local monitoring campaign, the objective should be to meet a 90 per cent data capture target wherever possible. To meet this requires regular calibration of the analysers and a rapid response time in the event of instrument breakdown. Before the monitoring campaign, it will need to be decided whether spare analysers are available to be swapped in rapidly in the event of a failure, or whether a contract needs to be set up with a reputable service and maintenance company to provide this service. If a service contract is put in place, a typical target response time would be 48 hours for the contractor to either repair or replace a faulty analyser.

We are The Environment Agency. It's our job to look after your environment and make it **a better place** – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

Published by:

Environment Agency  
Rio House  
Waterside Drive, Aztec West  
Almondsbury, Bristol BS32 4UD  
Tel: 0870 8506506  
Email: [enquiries@environment-agency.gov.uk](mailto:enquiries@environment-agency.gov.uk)  
[www.environment-agency.gov.uk](http://www.environment-agency.gov.uk)

© Environment Agency

All rights reserved. This document may be reproduced with prior permission of the Environment Agency.