

# Report

## **Preliminary Assessment of ozone levels in the UK**

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

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AEAT/ENV/R/1528/Issue 1  
August 2003

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# 1 Introduction

The Framework Directive<sup>1</sup> establishes a system under which limit values or target values for specified ambient air pollutants will be set within the EU. The 3<sup>rd</sup> Daughter Directive<sup>2</sup> sets target values and long-term objectives for ozone.

Article 15 of the 3<sup>rd</sup> Daughter Directive specifies that the provisions of that Directive are to be transposed into national law by 9 September 2003. The UK will begin the assessment of ambient air quality for ozone, required by Article 6 of the Framework Directive, from 1 January 2004.

Monitoring of air quality in the UK is carried out through national networks of air quality monitoring stations (e.g. the Automatic Urban and Rural Networks and hydrocarbon networks). In addition, local authority funded monitoring activities operate throughout the UK, although in general, these are not combined with the national network. This report describes how the national monitoring networks are to be expanded to meet the requirements of the Framework Directive and 3<sup>rd</sup> Daughter Directive on ozone. This expansion will be achieved in many cases by the incorporation of local authority monitoring stations into the national network.

## 2 Preliminary Assessment

Under Article 5 of The Framework Directive (see Appendix 1), a requirement has been placed upon Member States to undertake a preliminary investigation of ambient air quality, prior to the implementation of the Daughter Directive relating to ozone.

The objectives of this assessment are to establish estimates of the overall distribution and levels of ozone, and to identify additional monitoring requirements, which may be necessary in order to fulfil obligations in the Framework and 3<sup>rd</sup> Daughter Directive. This report provides details of the number of additional monitoring locations that will be required for the assessment of ozone in the UK. A description is provided of the methods that have been applied in the UK, by **netcen** on behalf of the Department for Environment, Food and Rural Affairs (Defra), the Scottish Executive, Welsh Assembly Government and the Department of the Environment in Northern Ireland.

## 3 General approach

For the purpose of this assessment levels of ozone throughout the UK have been assessed using measurement data for 2001 from the UK's national Automatic Urban and Rural Networks (AURN). Information provided by this monitoring network has also been supplemented by high resolution empirical model outputs, based upon the techniques used by UK expert advisory groups<sup>3</sup> and

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<sup>1</sup> Council Directive 96/62 EC, of 27 September 1996 on ambient air quality assessment and management, (The Framework Directive). From the Official Journal of the European Communities, 21.11.1996, En Series, L296/55.

<sup>2</sup> Council Directive 2002/3/EC, of 12 February 2002 relating to ozone in ambient air, (The 3<sup>rd</sup> Daughter Directive). From the Official Journal of the European Communities, 9.3.2002. En series, L67/14.

<sup>3</sup> NEG-TAP 2001, Transboundary Air Pollution: Acidification, Eutrophication and Ground-level ozone in the UK. ISBN 1 870393 61 9. Prepared by the National Expert Group on Transboundary Air Pollution (NEG-TAP) on behalf of the Department for Environment, Food and Rural Affairs, the Scottish Executive, Welsh Assembly Government and the Department of the Environment in Northern Ireland.

developed by the Centre for Ecology and Hydrology<sup>4</sup>. The empirical model outputs have been used as a screening tool to inform on the general levels and distribution of ozone in locations with no monitoring. The models draw heavily upon measurement data from the UK's automatic urban and rural network (AURN), and are calibrated to these networks.

This approach, which combines highly accurate measured data and information from screening tools provides a comprehensive and consistent means of estimating pollutant concentrations throughout the whole of the UK. In order to check that the modelled exceedence statistics provided by this approach have not been systematically underestimated, a comparison with measured exceedence data for the 2000 calendar year has been performed at sites within the current AURN. These comparisons are presented in Appendix 4. Agreement between modelled exceedences at each monitoring location and measured exceedence statistics is generally good.

The UK has been divided into 16 zones, based on official Government Office boundaries within England and boundaries provided or authorised by the relevant Government offices within Scotland, Wales and Northern Ireland. A further 28 agglomeration zones (areas of urban population > 250,000) have also been agreed. These were based on 1991 Census information, Government geographical information system data on urban areas for England and Wales<sup>5</sup>, urban localities information in Scotland<sup>6</sup> and CORINE land cover information within Northern Ireland<sup>7</sup>. UK zones and agglomerations are presented in Figure 1. It will be noted from Figure 1 that Greater London is defined as both an agglomeration and a zone. This is a result of a specific Government Office region being assigned to this area and the urban population exceeding 250,000. For the purpose of this assessment, Greater London will be treated as an agglomeration only. Monitoring requirements within each zone and agglomeration have been assessed separately.

Measured and modelled ozone concentrations within each zone and agglomeration have been compared with the relevant long-term objectives and target values, defined in the 3<sup>rd</sup> Daughter Directive and summarised in Table 1 below (see also Appendix 2).

**Table 1 Summary of target values and long-term objectives for ozone under the 3<sup>rd</sup> Daughter Directive**

	Parameter	Target/objective
1. Target value for the protection of human health for 2010	Maximum daily 8-hour mean	120 µg/m <sup>3</sup> not to be exceeded on more than 25 days per calendar year averaged over three years
2. Target value for the protection of vegetation for 2010	AOT40, calculated from 1h values from May to July	18,000 µg/m <sup>3</sup> .h averaged over five years
1. Long-term objective for the protection of human health	Maximum daily 8-hour mean within a calendar year.	120 µg/m <sup>3</sup>
2. Long-term objective for the protection of vegetation	AOT40, calculated from 1h values from May to July	6,000 µg/m <sup>3</sup> .h

Areas requiring additional monitoring have been identified by an exceedence of the long-term objective and an examination of the coverage provided by the current automatic monitoring network of these areas. The number of additional monitoring sites required has been calculated from the population of the individual zones and agglomerations.

Annex V of the 3<sup>rd</sup> Daughter Directive presents the minimum monitoring requirements assuming fixed monitoring as the sole source of information (see Appendix 3). However, Article 9 of the Directive also recognises the value of supplementary information sources (models, emissions inventories, indicative monitoring) and specifies that the overall monitoring burden can be reduced where such techniques are available, provided that;

<sup>4</sup> Coyle M, Smith R, Stedman J, Weston K and Fowler D, 2002. Quantifying the spatial distribution of surface ozone concentration in the UK. *Atmospheric Environment*, 36 (2002) 1013-1024.

<sup>5</sup> Personal communication with Carol Hyrenkiwicz of the DETR Planning and Land Use Statistics Division, GIS Unit, 1998.

<sup>6</sup> Personal communication with Stuart Gardner of the Scottish Executive Geographic Information Service, 1998.

<sup>7</sup> Corine Land Cover of Europe, produced by the European Topic Centre on Land Cover, July 8th, 1997. European Environment Agency, Environment Satellite Data Centre, Sweden.

1. Supplementary techniques provide adequate level of information for assessment of air quality in relation to target, information and alert thresholds.
2. The number of monitoring stations, in combination with other assessment techniques, fulfil the Data Quality Objectives (DQOs) outlined in Sections I and II of Annex VII of the Directive.
3. At least 1 monitoring station is deployed per 2,000,000 inhabitants of a zone or agglomeration, or 1 per 50,000 km<sup>2</sup> which ever results in the most sites.
4. Each zone/agglomeration has at least 1 monitoring station.
5. NO<sub>2</sub> is measured at all remaining monitoring stations except rural background locations.

Based on the availability of supplementary assessment techniques in the UK (the empirical maps of ozone presented in this report and other more complex models, described in Section 3.1, below), it has been assumed that the minimum requirements laid out in Section I Annex V of the Directive are superseded by those presented by paragraphs 1 (a-e) of Article 9 and summarised in bullets 1-5 above.

### **3.1 SUPPLEMENTARY INFORMATION TECHNIQUES IN THE UK**

The empirical model outputs presented in this report provide a useful screening tool for an assessment of the general levels and distribution of ozone. However it is recognised that the approach used by these models may over simplify the mechanisms effecting ozone levels and as a result may be subject to uncertainties that are as yet unquantified. In recent years, Defra and the devolved administrations have funded the development of the Ozone Source Receptor Model (OSRM) with the aim of developing a complex model for estimating ozone levels and testing emission scenarios for limiting ozone episodes. The OSRM is a Lagrangian based computer model incorporating atmospheric chemistry and realistic air mass back trajectories. The model can be used to derive a range of ozone exposure metrics across the UK and is one of the proposed supplementary techniques to be used for reporting of modelled concentrations of ozone to the Commission from 2005.

The OSRM incorporates the following features,

- air mass trajectories, calculated from global meteorological datasets
- recent emission inventories, from the National Atmospheric Emission Inventory programme for the UK and from EMEP for Europe
- temporal emission factors to simulate the hour-of-day, the day-of-week and the seasonal variations in the emissions
- a new biogenic VOC emission inventory has been defined in terms of emission potentials
- the same chemical mechanism as that used in the STOCHEM and ELMO models<sup>8</sup>
- dry deposition processes represented using a conventional resistance approach, in which the rate of dry deposition is characterised by a deposition velocity
- simulation of a full diurnal cycle to represent ozone depletion at night
- the effect of climate change using concentration fields derived from the STOCHEM model for the present day and future atmospheres.

A full intercomparison of the available supplementary techniques is planned in 2004 to identify the most appropriate supplementary assessment techniques for the annual reporting phases commencing in 2005.

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<sup>8</sup> It is intended to implement the Common Reactive Intermediate mechanism (derived from the MCM) when it has been converted into a FORTRAN code and provided it does not affect the runtime significantly.

# 4 Methodology

Ozone concentrations throughout the UK have been assessed using measurements from the AURN and modelled data at locations away from busy roads which characterise urban and rural background conditions. Modelled estimates of ozone concentrations in 2001 have been derived using empirical models<sup>9</sup> for both the maximum daily 8-hour mean and AOT40 metrics. Automatic monitoring data are incorporated into the empirical models used. Measured and modelled levels have been compared with the long-term objectives for ozone within each agglomeration and non-agglomeration zone within the UK. Where exceedence of a long-term objective was identified this triggered the requirement to monitor in each agglomeration and non-agglomeration zone. Exceedence the target values have also been calculated for information only, exceedences of the target values do not impact on the monitoring required for compliance with the Directive.

Maps showing measured and modelled exceedences of the long-term objectives have been compiled for the UK. Measurements and modelled concentrations are presented for non-roadside/kerbside locations. Figure 2 and Figure 3 present measured and modelled estimates of the number of days exceeding the maximum daily 8-hour mean long-term objective for ozone ( $120 \mu\text{g}\cdot\text{m}^{-3}$  as a maximum daily 8-hour mean). Figure 4 and Figure 5 present similar plots of measured and modelled exceedence of the AOT40 long-term objective for the protection of vegetation and ecosystems.

Exceedences of the target values for the protection of human health and for the protection of vegetation and ecosystems are shown in Figure 6 and Figure 7. Target value exceedences are based on an average number of exceedences per year, over 3 and 5 year period, for human health and vegetation/ecosystems protection respectively.

In order to check the performance of the ozone models and to ensure that exceedence statistics are not systematic underestimated, modelled data and measured exceedence statistics for 2001 have been compared. These data are presented in Appendix 4 and show generally good agreement between modelled and measured levels throughout the UK zones and agglomerations.

## 4.1 OBSERVATIONS AND PROPOSALS

### 4.1.1 Exceedences relative to the long-term objectives

Figure 2 indicates that measured exceedences of the long-term objective for human health were routinely found in the majority of zones and agglomerations with monitoring in the UK during 2001. There were two exceptions to this observation. Both Glasgow and Edinburgh Centre monitoring stations measured levels below the long-term objective for human health. Observations based on measurements are confirmed by the estimated exceedences during 2001 derived from the empirical ozone model. Figure 3 presents modelled exceedences and indicates that the long-term objective for human health was likely to have been exceeded on at least one occasion in all UK zones and agglomerations.

Figure 4 shows that measured exceedence of the long-term objective for the protection of vegetation and ecosystems was widespread throughout England during 2001. A total of 23 monitoring station measured levels in excess of the AOT40 long-term objective ( $6,000 \mu\text{g}/\text{m}^{-3}\cdot\text{h}$ ). Highest levels were measured in the South East at Teddington in London ( $12,118 \mu\text{g}/\text{m}^{-3}\cdot\text{h}$ ) Lullington Heath ( $11,580 \mu\text{g}/\text{m}^{-3}\cdot\text{h}$ ) and Rochester ( $10,470 \mu\text{g}/\text{m}^{-3}\cdot\text{h}$ ). Figure 5 presents the modelled AOT40 metric and indicates that zones and agglomerations in southern and eastern areas of England and Wales and eastern areas of Scotland are likely to have AOT40 levels in excess of the long-term objective for the protection of vegetation and ecosystems.

A single measured or modelled exceedence of either the long-term objective for the protection of human health or vegetation and ecosystems triggers a requirement to monitor ozone.

<sup>9</sup> Personal communication with Mhairi Coyle, Centre for Ecology and Hydrology, Penicuik, Scotland, 2003.

#### 4.1.2 Exceedences relative to target values

The target value for the protection of human health allows for no more than 25 exceedences of  $120 \mu\text{g m}^{-3}$  (as a maximum daily running 8-hour mean) per calendar year (averaged over 3 years). Figure 6, presents the average number days exceeding  $120 \mu\text{g m}^{-3}$  per year between 1999 and 2001 for background monitoring stations in the AURN. On average, levels were highest at Lullington Heath where  $120 \mu\text{g m}^{-3}$  was exceeded on 13 days a year between 1999 and 2001. Levels of exceedence of this magnitude are well below the target value of 25 days.

Similarly, the measured data indicate that levels throughout the UK are below the target value for the protection of vegetation and ecosystems, as illustrated by Figure 7. The highest 5-year average of AOT40 measured between 1997 and 2001 was also measured at Lullington Heath ( $9,091 \mu\text{g/m}^{-3}\cdot\text{h}$ ), approximately 50% of the target value of  $18,000 \mu\text{g/m}^{-3}\cdot\text{h}$ .

## 4.2 MONITORING REQUIREMENTS IN AGGLOMERATIONS

The minimum number of monitoring stations required within agglomerations defined by Annex V of the Daughter Directive on ozone (see Appendix 3) assumes that fixed monitoring is the sole source of information. Based on the guidance presented by Annex V and the exceedences of the long-term objective presented in Figures 2 to 5, the minimum number of monitoring stations required in UK agglomerations, is presented in Table 2 (see page 6) by the '*Minimum Number of Stations A*' statistic.

Article 9 of the Directive sets out the minimum monitoring requirement in agglomerations where supplementary sources of information on ozone levels are also available. Article 9 sets out a requirement within agglomerations of 1 co-located ozone and NO<sub>x</sub> monitoring station per 2 million inhabitants, provided that other criteria are also met (see Section 3). Based on guidance provided by Article 9 and the exceedences of the long-term objective presented in Figures 2 to 5, the minimum number of monitoring stations required in UK agglomerations, is presented in Table 2 by the '*Minimum Number of Stations B*' statistic. All monitoring must be located at urban background or suburban locations, away from major emissions sources which may be expected to effect ozone levels.

Table 2 identifies agglomeration zones with measured or modelled exceedences of the long-term objectives. Additional monitoring required for agglomerations with exceedences of the long-term objectives, have been calculated based on the population of the agglomeration and coverage from the monitoring network as of January 2003.

Table 2 shows that when the current network of automatic monitoring stations and the supplementary assessment methods are taken into account, a total of 3 additional co-located NO<sub>2</sub> and ozone monitoring stations and the recommissioning of the monitoring station in the Reading agglomeration are required for compliance with the Directive. There are no additional monitoring requirements for agglomeration zones in Scotland, Wales and Northern Ireland.



**Table 2 Monitoring stations for proposed urban and suburban ozone network in agglomerations**

Zone	Population*	Long-term objective exceeded? **		Minimum number of stations		Existing urban background & suburban co-located NO <sub>2</sub> /O <sub>3</sub> stations	Additional Monitoring required
		Max daily 8-hour	AOT40	A	B		
Greater London Urban Area	7650944	Yes	Yes	6	4	13	-
West Midlands Urban Area	2296180	Yes	Yes	4	2	4	-
Greater Manchester Urban Area	2277330	Yes	No	4	2	4	-
West Yorkshire Urban Area	1445981	Yes	No	3	1	2	-
Glasgow Urban Area	1315544	Yes	Yes	3	1	1	-
Tyneside	885981	Yes	Yes	2	1	1	-
Liverpool Urban Area	837998	Yes	No	2	1	1	-
Sheffield Urban Area	633362	Yes	Yes	2	1	2	-
Nottingham Urban Area	613726	Yes	Yes	2	1	1	-
Bristol Urban Area	522784	Yes	Yes	2	1	1	-
Belfast Urban Area	475987	Yes	No	1	1	1	-
Brighton/Worthing/Littlehampton	437592	Yes	Yes	1	1	None	1 <sup>a</sup>
Leicester Urban Area	416601	Yes	Yes	1	1	1	-
Edinburgh Urban Area	416232	Yes	Yes	1	1	1	-
Portsmouth Urban Area	409341	Yes	Yes	1	1	None	1 <sup>b</sup>
Teesside Urban Area	369609	Yes	Yes	1	1	2	-
The Potteries	367976	Yes	Yes	1	1	1	-
Bournemouth Urban Area	358321	Yes	Yes	1	1	None	1 <sup>c</sup>
Reading/Wokingham Urban Area	335757	Yes	Yes	1	1	None	1 <sup>d</sup>
Coventry/Bedworth	331248	Yes	Yes	1	1	1	-
Kingston upon Hull	310636	Yes	Yes	1	1	1	-
Cardiff Urban Area	306904	Yes	Yes	1	1	1	-
Southampton Urban Area	276752	Yes	Yes	1	1	1	-
Swansea Urban Area	272456	Yes	Yes	1	1	1	-
Birkenhead Urban Area	270207	Yes	No	1	1	1	-
Southend Urban Area	266749	Yes	Yes	1	1	1	-
Blackpool Urban Area	261355	Yes	No	1	1	1	-
Preston Urban Area	256411	Yes	Yes	1	1	1	-

a. Requires additional NO<sub>x</sub>, ozone and monitoring enclosure

b. Ozone monitor required at existing NO<sub>x</sub> station(s)

c. Affiliate existing ozone monitor

d. Relocation of existing monitoring station

\* Population statistics based on the 1991 National Census

\*\* Exceedence category based on measured and modelled data

### 4.3 MONITORING REQUIREMENTS IN NON-AGGLOMERATION ZONES

The amount of monitoring required within non-agglomeration zones in the UK is regulated by the same criteria specified for agglomeration zones under Article 9 of the Directive. However, within non-agglomeration zones, co-located NO<sub>2</sub> and ozone monitoring stations must be located at suburban and rural background locations. A minimum requirement of 1 co-located station per 2 million inhabitants of a zone remains or 50,000 km<sup>2</sup> whichever yields the greatest number of sites.

Table 4 (see page 8) identifies non-agglomerations zones with measured or modelled exceedences of the long-term objectives. The current number of co-located NO<sub>2</sub> and ozone monitoring stations<sup>10</sup> which meet the suburban and rural background siting criteria specified by Annex IV of the Directive are also indicated. As for agglomerations zones, the minimum monitoring requirement assuming fixed monitoring as the sole source of information is presented by the 'Minimum Site Number A' statistic. Monitoring requirements taking into account supplementary assessment techniques are presented by the 'Minimum Site Number B' statistic. Table 4 shows that when the current network of automatic monitoring stations and the supplementary assessment methods are taken into account, a total of 8 additional co-located NO<sub>2</sub> and ozone monitoring stations are required for compliance with the Directive within non-agglomerations zones in England. A further 4 monitoring stations are required in Scotland and 2 in Wales. No additional monitoring requirements were identified for Northern Ireland.

### 4.4 MONITORING REQUIREMENTS AT RURAL BACKGROUND LOCATIONS

Annex V of the Daughter Directive for ozone presents a requirement for monitoring of ozone at rural background locations.

Section I Annex V of the Directive specifies that 1 measurement station must be located in a rural background locations for every 50,000 km<sup>2</sup> of land mass. The UK covers approximately 244,767 km<sup>2</sup>, as a result 5 monitoring locations are required in rural background locations for compliance with the Directive. Table 3 presents the monitoring stations in the UK network for compliance with rural background monitoring requirements. The location types described as rural background by the Directive have historically been known as 'remote' locations within the UK.

**Table 3 Monitoring stations proposed for rural background monitoring requirement**

Monitoring Location	Pollutants measured
Strath Vaich	O <sub>3</sub>
Great Dun Fell	O <sub>3</sub>
Lough Navar	O <sub>3</sub>
Narberth	O <sub>3</sub> , SO <sub>2</sub> , PM10 and NO <sub>x</sub>
Sibton	O <sub>3</sub>

Automatic monitoring of NO<sub>2</sub> at rural background location is not required.

<sup>10</sup> Based on AURN network statistics January 2003.

**Table 4 Additional monitoring stations for proposed rural and suburban ozone network in zones**

Zone	Population*	Long-term objective exceeded? **		Minimum number of stations		Existing suburban & rural background co-located NO <sub>2</sub> /O <sub>3</sub> stations	Additional Monitoring required
		Max daily 8-hour	AOT40	A	B		
Eastern	4788766	Yes	Yes	6	3	4	-
South West	3728319	Yes	Yes	5	2	None	2 <sup>a</sup>
South East	3702634	Yes	Yes	5	2	3	-
East Midlands	2923045	Yes	Yes	5	2	1	1 <sup>d</sup>
North West & Merseyside	2823559	Yes	Yes	5	2	None	2 <sup>a,b</sup>
Yorkshire & Humberside	2446545	Yes	Yes	4	2	1	1 <sup>a</sup>
West Midlands	2154783	Yes	Yes	4	2	1	1 <sup>e</sup>
Central Scotland	1628460	Yes	Yes	3	1	None	1 <sup>c</sup>
South Wales	1544120	Yes	Yes	3	1	None	1 <sup>d</sup>
North East	1287979	Yes	Yes	3	1	None	1 <sup>e</sup>
Northern Ireland	1101868	Yes	No	3	1	1	-
North East Scotland	933485	Yes	Yes	2	1	None	1 <sup>b</sup>
North Wales	582488	Yes	Yes	2	1	None	1 <sup>a</sup>
Highland	364639	Yes	Yes	2	1	None	1 <sup>e</sup>
Scottish Borders	246659	Yes	Yes	1	1	None	1 <sup>a</sup>

- a. NO<sub>x</sub> monitors required at existing ozone station(s)
- b. Ozone monitor required at existing NO<sub>x</sub> station(s)
- c. Affiliate existing NO<sub>x</sub> monitoring
- d. Affiliate existing ozone monitoring
- e. Requires additional NO<sub>x</sub>, ozone and monitoring enclosure

\* Population statistics based on the 1991 National Census  
 \*\* Exceedence category based on measured and modelled data

## **4.5 MONITORING REQUIREMENTS FOR OZONE PRECURSORS**

Article 9 (3) of the Directive requires Member States to measure a suite of ozone precursors in at least 1 urban background location within their territory. Ozone precursors are defined as NO<sub>x</sub> and volatile organic compounds (VOC) and recommendations on the type of compounds to be measured are provided in Annex VI of the Directive (see Appendix 5).

There is currently one location within the UK's benzene monitoring network (London Marylebone Road) which is capable of measuring 27 out of the 31 recommended VOC presented in Annex VI of the Directive. However, the Marylebone Road is located at the roadside and the specified siting criteria for the precursor monitoring station is urban background. As a result monitoring of precursors will be recommissioned at the Eltham AURN urban background monitoring station.

In addition to the sites presented above, a further 3 automatic stations measure a smaller suite of VOC (benzene, 1-3 butadiene, toluene, m p and o xylenes and ethylbenzene). These monitoring stations are located at the Harwell (rural), Cardiff Centre and Glasgow Centre (urban background) AURN stations.

## 5 Achieving compliance

Ozone levels have been assessed throughout the UK using measured and modelled data. On the basis of the assessments and analyses presented in this report, the minimum number of additional automatic monitoring stations have been identified for areas with measured or modelled exceedences of the long-term objectives for ozone.

The recommendations for additional monitoring are summarised in Table 5, below. Fixed monitoring will be supplemented by information from other sources (empirical maps, OSRM etc.) in all zones and agglomerations. Monitoring stations already available in the current monitoring network have also been taken into account.

**Table 5 Summary of monitoring requirements for minimum compliance with the ozone Directive**

Additional monitoring stations	3
Additional NO <sub>2</sub> analysers in existing monitoring stations	11
Additional O <sub>3</sub> analysers in existing monitoring stations	10
Additional VOC monitoring	1

By implementing the NO<sub>2</sub> and ozone monitoring presented in Table 5 a total of 18 additional co-located monitoring stations will be commissioned. The additional monitoring needed for formal compliance with the Directive will be satisfied by a process of affiliation of existing local authority monitoring stations and also by direct funding of new monitoring sites from the UK Government.

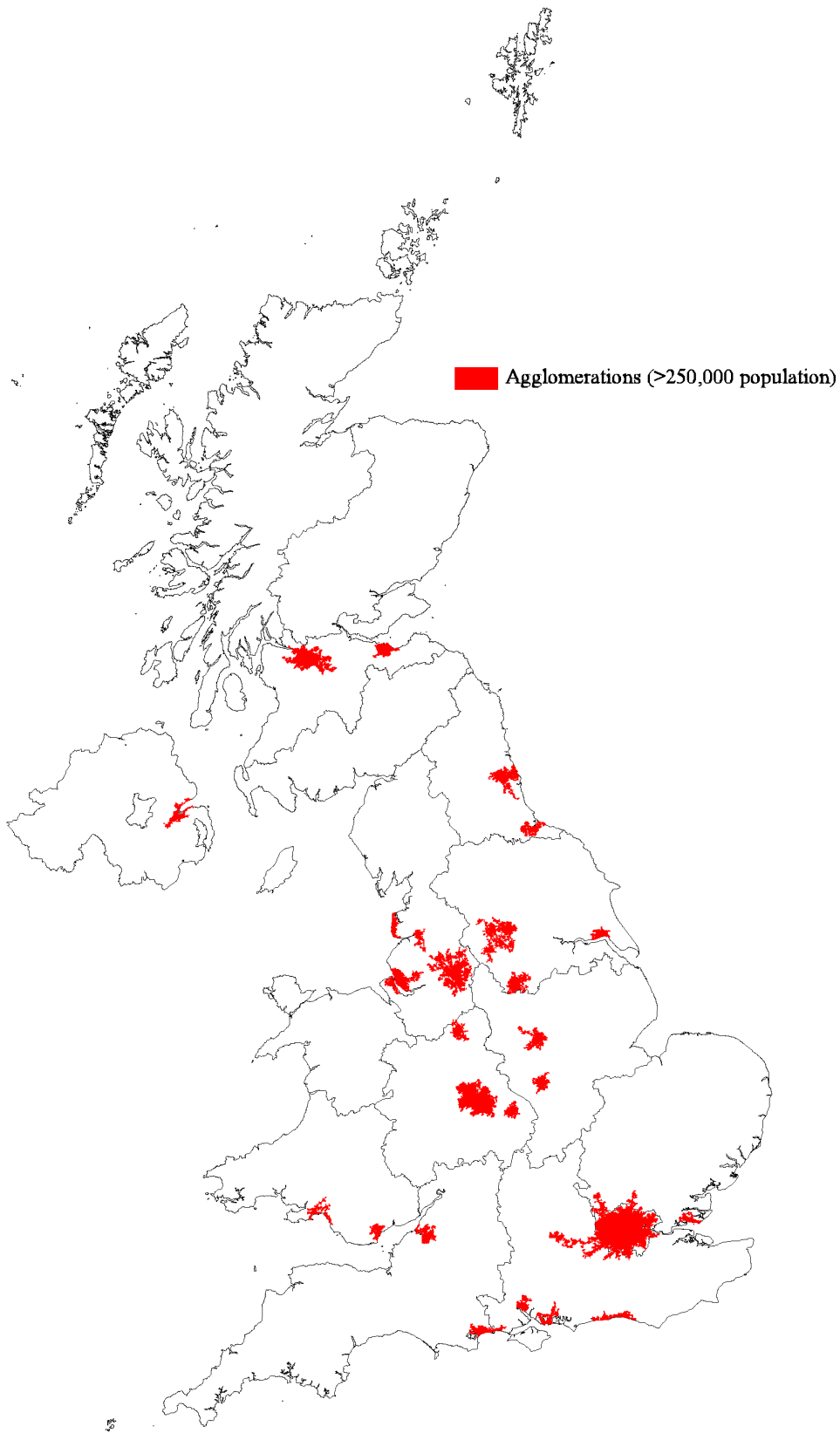
Table 6 below presents the equipment and monitoring sites targeted for the expansion of the AURN to accommodate the 3<sup>rd</sup> Daughter Directive on ozone.

**Table 6 Proposed target sites for expansion of the AURN under the 3<sup>rd</sup> Daughter Directive on ozone**

Zone/Agglomeration	Equipment required	Target site
Greater London Urban Area	VOC monitoring	Existing Eltham AURN station
Brighton/Hove/Littlehampton	NO <sub>2</sub> & O <sub>3</sub> monitors	Preston Park
Portsmouth Urban Area	O <sub>3</sub> monitor	Existing Portsmouth AURN stations
Bournemouth Urban Area	O <sub>3</sub> monitor	Existing Bournemouth AURN stations
Reading/Wokingham Urban Area	Relocate existing monitoring	Appropriate urban background location
South West	2 × NO <sub>2</sub> monitor	Yarner Wood & Somerton AURN stations
East Midlands	Affiliate existing O <sub>3</sub> monitor	Existing Northampton AURN station
North West & Merseyside	NO <sub>2</sub> & O <sub>3</sub> monitors	Existing Glazebury & Wigan Leigh AURN stations respectively
Yorkshire & Humberside	NO <sub>2</sub> monitor	Existing High Muffles AURN station
West Midlands	NO <sub>2</sub> , O <sub>3</sub> & monitoring enclosure	Leominster
South Wales	Affiliate existing O <sub>3</sub> monitor	Existing Cwmbran AURN station
North Wales	NO <sub>2</sub> monitor	Existing Aston Hill AURN station
Central Scotland	Affiliate existing NO <sub>2</sub> monitor	Existing Bush AURN station
North East Scotland	O <sub>3</sub> monitor	Existing Aberdeen AURN stations
Scottish Borders	NO <sub>2</sub> monitor	Existing Eskdalemuir AURN station
North East	NO <sub>2</sub> , O <sub>3</sub> & monitoring enclosure	Ashington
Highlands	NO <sub>2</sub> , O <sub>3</sub> & monitoring enclosure	Fort William

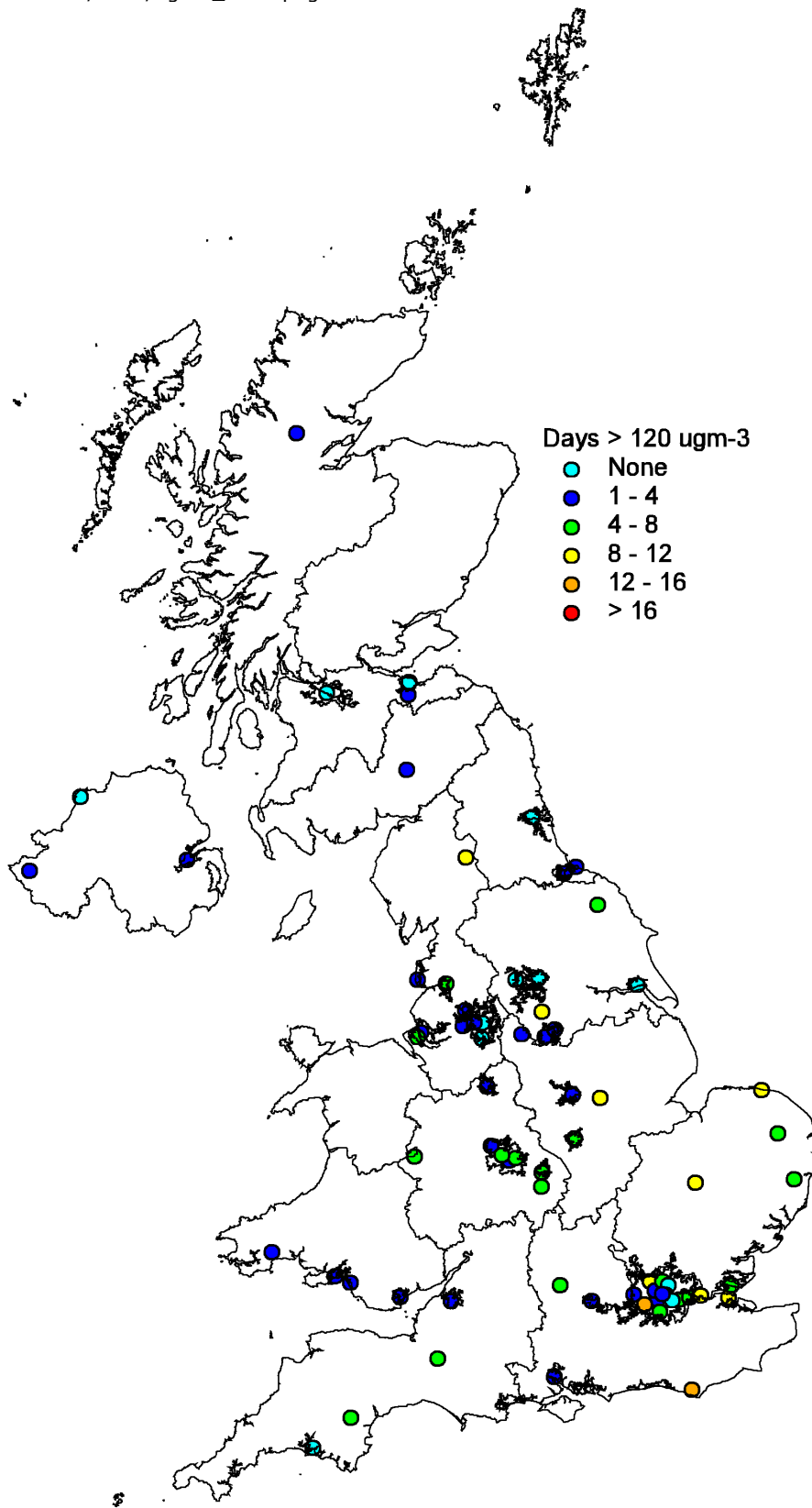
**Figure 1 Preliminary Assessment zones and agglomerations**

Ref. netcen/12012000/gloms.shp,art5zones.shp/v6/TB



**Figure 2 Measured exceedences of the long-term objective for the protection of human health in 2001 at all non-roadside/kerbside sites in UK**

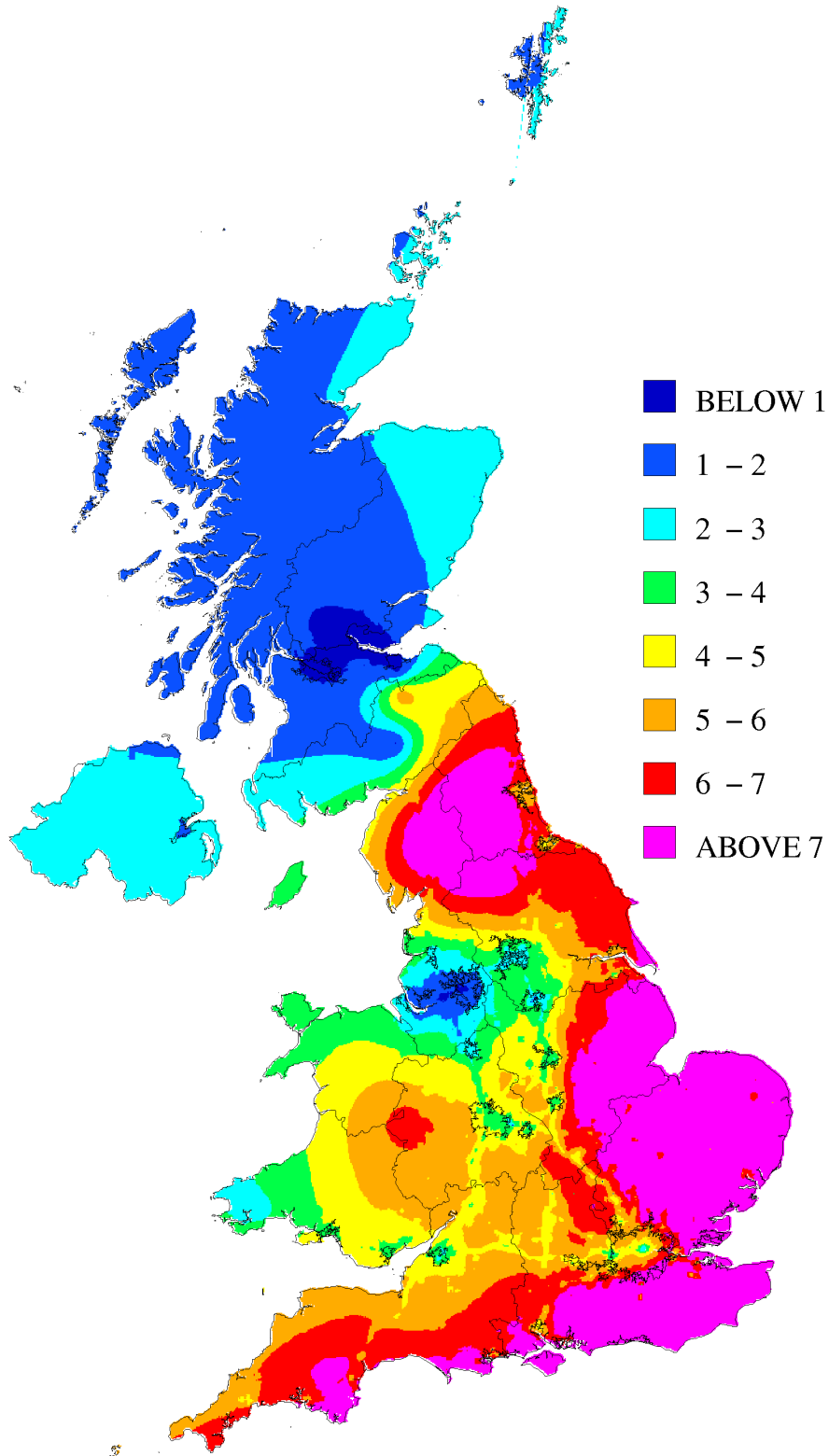
Ref. netcen/16072003/o3dd/dgt60\_2001.png



Long-term objective = 120 µg-m<sup>-3</sup> as a daily maximum of running 8 hour means

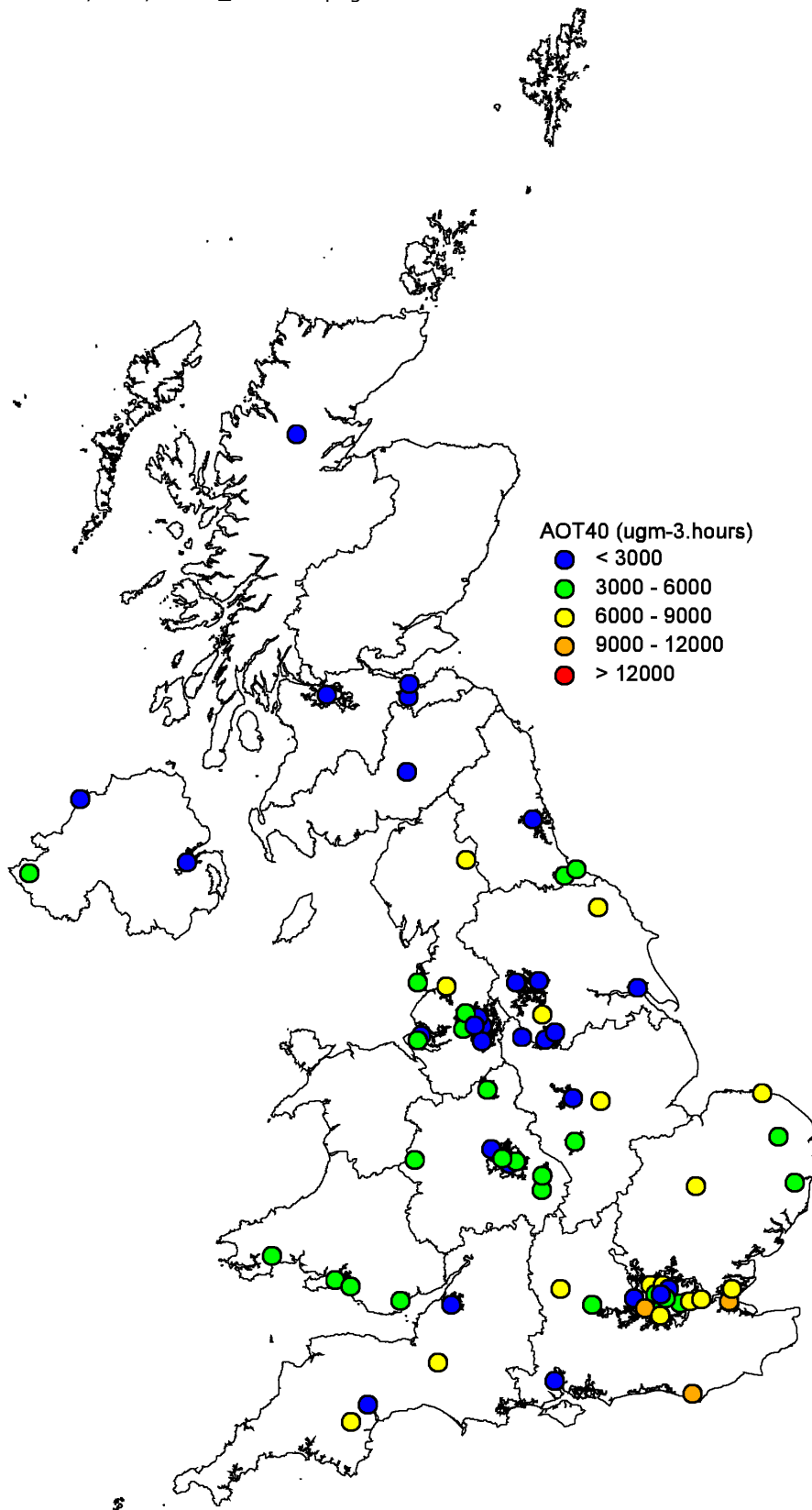
**Figure 3 Modelled exceedence of the long-term objective for the protection of human health in 2001 (Days > 120  $\mu\text{g}\text{m}^{-3}$  as a maximum daily 8-hour mean)**

Ref. Mhairi Coyle, Centre for Ecology and Hydrology, Edinburgh/15072003/dgt60\_01ui





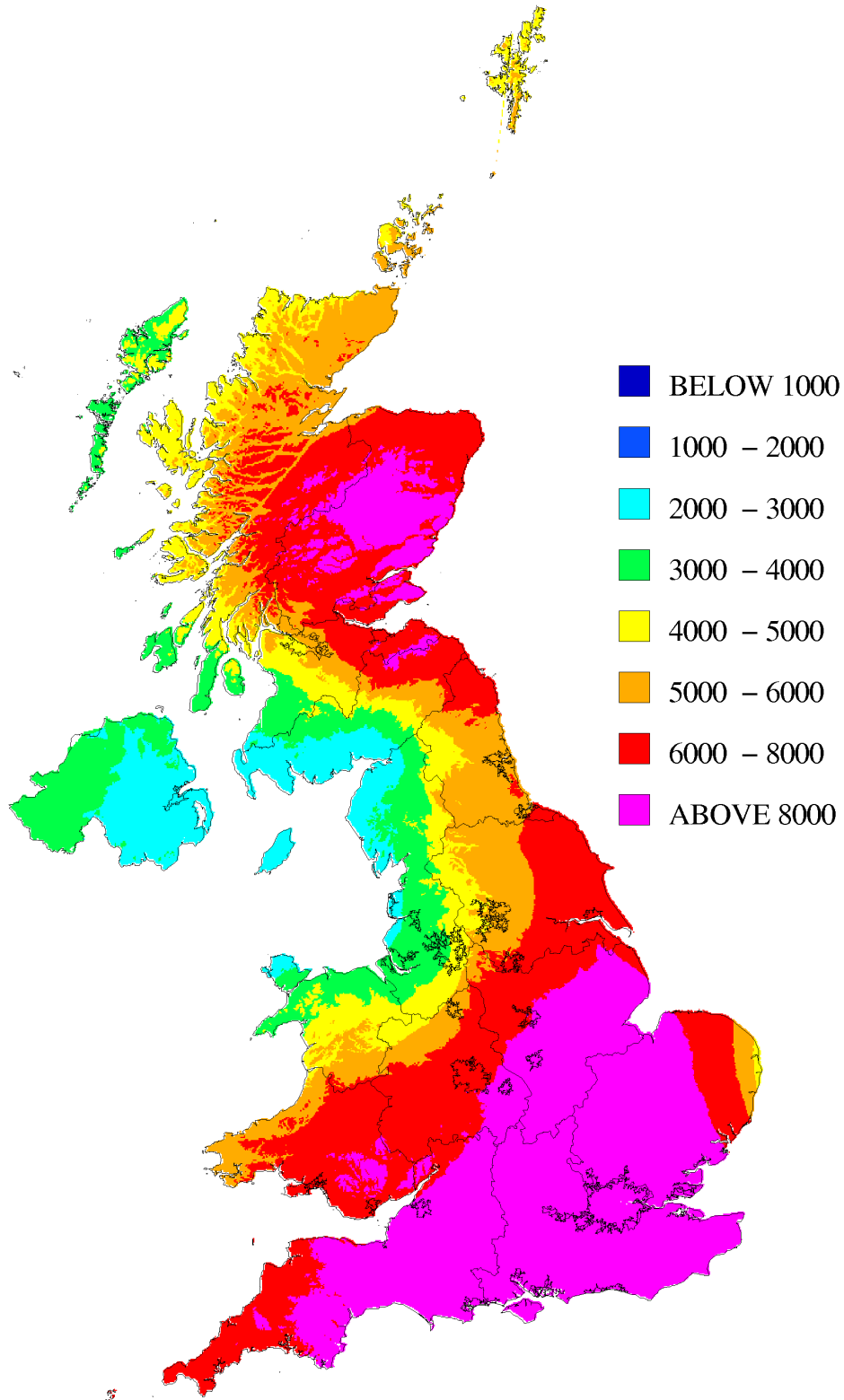
**Figure 4 Measured exceedences of the long-term objective for the protection of vegetation and ecosystems in 2001 at all non-roadside/kerbside sites in UK**  
Ref. netcen/16072003/o3dd/ aot40\_2001aun.png



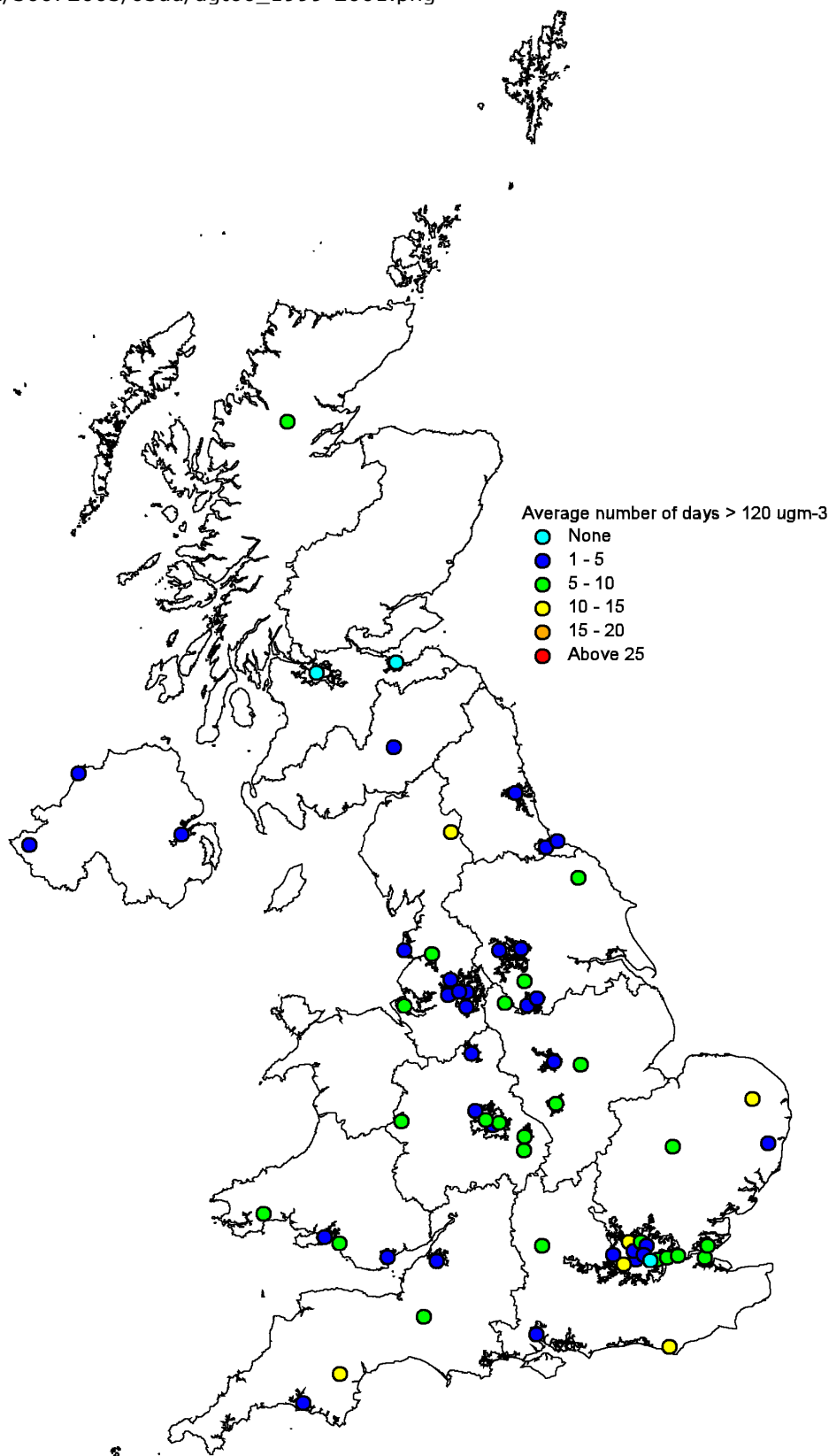
Long-term objective = AOT40 not greater than  $6000 \mu\text{g}/\text{m}^3 \text{ h}$ .

**Figure 5 Modelled exceedences of the long-term objective for the protection of vegetation and ecosystems in 2001 (AOT40  $\mu\text{g}\text{m}^{-3}\cdot\text{hours}$ )**

Ref. Mhairi Coyle, Centre for Ecology and Hydrology, Edinburgh/15072003/aot40w\_01ug



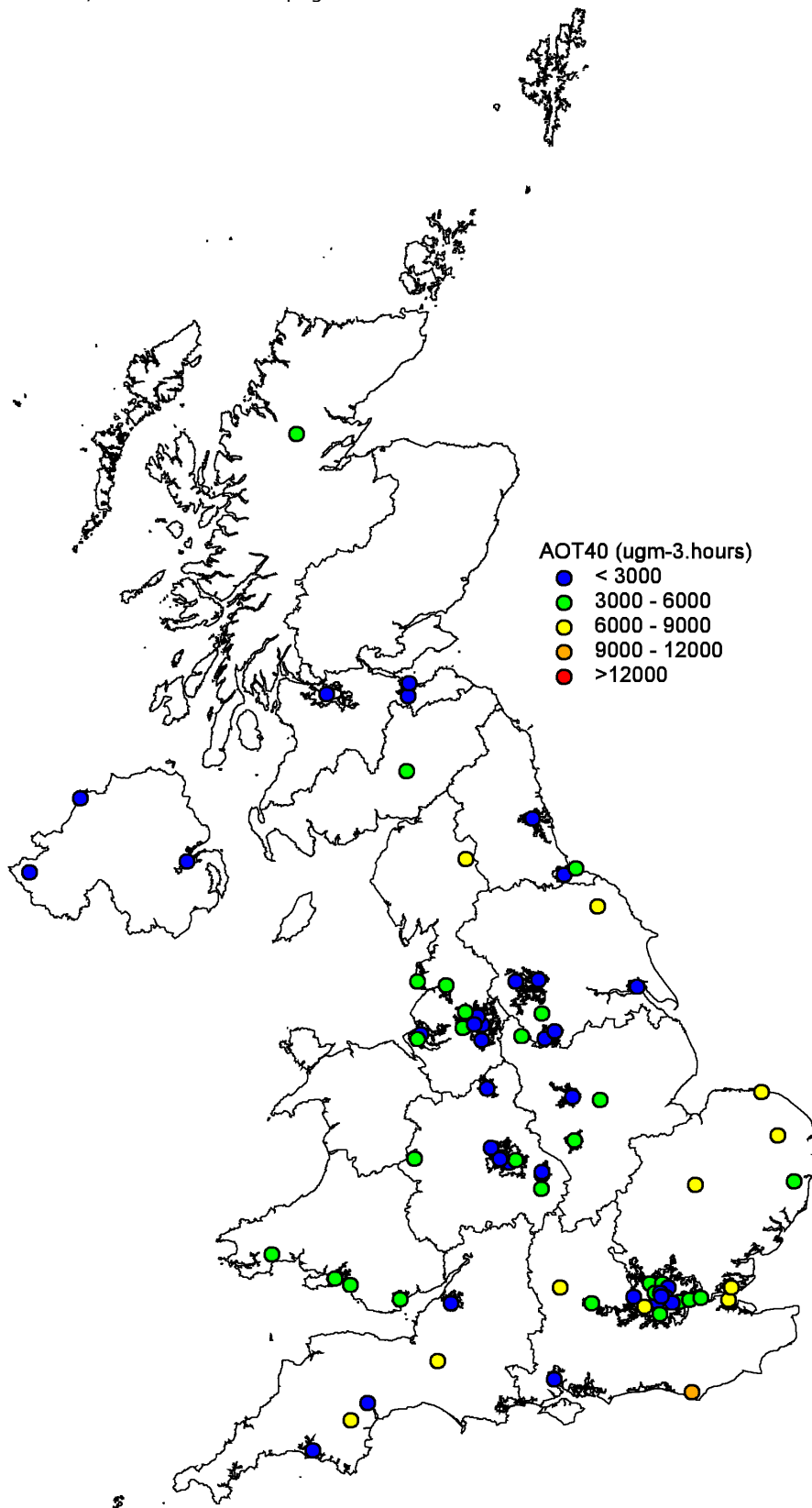
**Figure 6 Measured exceedences of the target value for the protection of human health 1999-2001 at all non-roadside/kerbside sites in UK**  
 Ref. netcen/30072003/o3dd/dgt60\_1999-2001.png



Target value = 120  $\mu\text{g}/\text{m}^3$  as a daily maximum of running 8 hour means not to be exceeded more than 25 times per calendar year as an average over 3 years.

**Figure 7 Measured exceedences of the target value for the protection of vegetation and ecosystems 1997-2001 at all non-roadside/kerbside sites in UK**

Ref. netcen/30072003/aot40w1997-2001.png



Target value = AOT40 averaged over 5 years no greater than  $18000 \mu\text{g}/\text{m}^{-3}\cdot\text{h}$ .





# Appendices

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# **Appendix 1**

## **Framework Directive: Article 5**

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## **Article 5, Preliminary assessment of ambient air quality**

Member States which do not have representative measurements of the levels of pollutants for all zones and agglomerations shall undertake series of representative measurements, surveys or assessments to have data available in time for the implementation of the legislation referred to in Article 4 (1).

Source: Council Directive 96/62/EC

# **Appendix 2**

## **Daughter Directive Long-term Objectives and Target Values**

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## ANNEX I

## DEFINITIONS, TARGET VALUES AND LONG-TERM OBJECTIVES FOR OZONE

## I. Definitions

All values are to be expressed in  $\mu\text{g}/\text{m}^3$ . The volume must be standardised at the following conditions of temperature and pressure: 293 K and 101,3 kPa. The time is to be specified in Central European Time.

AOT40 (expressed in  $(\mu\text{g}/\text{m}^3)\text{-hours}$ ) means the sum of the difference between hourly concentrations greater than  $80 \mu\text{g}/\text{m}^3$  (= 40 parts per billion) and  $80 \mu\text{g}/\text{m}^3$  over a given period using only the 1 hour values measured between 8:00 and 20:00. Central European Time each day <sup>(1)</sup>.

In order to be valid, the annual data on exceedances used to check compliance with the target values and long-term objectives below must meet the criteria laid down in Section II of Annex III.

## II. Target values for ozone

	Parameter	Target value for 2010 (a) <sup>(1)</sup>
1. Target value for the protection of human health	Maximum daily 8-hour mean (b)	120 $\mu\text{g}/\text{m}^3$ not to be exceeded on more than 25 days per calendar year averaged over three years (c)
2. Target value for the protection of vegetation	AOT40, calculated from 1 h values from May to July	18 000 $\mu\text{g}/\text{m}^3\text{-h}$ averaged over five years (c)

(a) Compliance with target values will be assessed as of this value. That is, 2010 will be the first year the data for which is used in calculating compliance over the following three or five years, as appropriate.

(b) The maximum daily 8-hour mean concentration shall be selected by examining 8-hour running averages, calculated from hourly data and updated each hour. Each 8-hour average so calculated shall be assigned to the day on which it ends, i.e. the first calculation period for any one day will be the period from 17:00 on the previous day to 01:00 on that day; the last calculation period for any one day will be the period from 16:00 to 24:00 on the day.

(c) If the three or five year averages cannot be determined on the basis of a full and consecutive set of annual data, the minimum annual data required for checking compliance with the target values will be as follows:  
 — for the target value for the protection of human health: valid data for one year,  
 — for the target value for the protection of vegetation: valid data for three years.

<sup>(1)</sup> These target values and permitted exceedance are set without prejudice to the results of the studies and of the review, provided for in Article 11, which will take account of the different geographical and climatic situations in the European Community.

## III. Long-term objectives for ozone

	Parameter	Long-term objective (a)
1. Long-term objective for the protection of human health	Maximum daily 8-hour mean within a calendar year	120 $\mu\text{g}/\text{m}^3$
2. Long-term objective for the protection of vegetation	AOT40, calculated from 1 h values from May to July	6 000 $\mu\text{g}/\text{m}^3\text{-h}$

(a) Community progress towards attaining the long-term objective using the year 2020 as a benchmark shall be reviewed as part of the process set out in Article 11.

<sup>(1)</sup> Or the appropriate time for ultra-peripheral regions.

# **Appendix 3**

## **Monitoring requirements of the 3<sup>rd</sup> Daughter Directive**

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## ANNEX V

**CRITERIA FOR DETERMINING THE MINIMUM NUMBER OF SAMPLING POINTS FOR FIXED MEASUREMENT OF CONCENTRATIONS OF OZONE**

**I. Minimum number of sampling points for fixed continuous measurements to assess air quality in view of compliance with the target values, long-term objectives and information and alert thresholds where continuous measurement is the sole source of information**

Population (× 1 000)	Agglomerations (urban and suburban) (a)	Other zones (suburban and rural) (a)	Rural background
< 250		1	1 station/50 000 km <sup>2</sup> as an average density over all zones per country (b)
< 500	1	2	
< 1 000	2	2	
< 1 500	3	3	
< 2 000	3	4	
< 2 750	4	5	
< 3 750	5	6	
> 3 750	1 additional station per 2 million inhabitants	1 additional station per 2 million inhabitants	

(a) At least 1 station in suburban areas, where the highest exposure of the population is likely to occur. In agglomerations at least 50 % of the stations should be located in suburban areas.

(b) 1 station per 25 000 km<sup>2</sup> for complex terrain is recommended.

**II. Minimum number of sampling points for fixed measurements for zones and agglomerations attaining the long-term objectives**

The number of sampling points for ozone must, in combination with other means of supplementary assessment such as air quality modelling and colocated nitrogen dioxide measurements, be sufficient to examine the trend of ozone pollution and check compliance with the long-term objectives. The number of stations located in agglomerations and other zones may be reduced to one-third of the number specified in Section I. Where information from fixed measurement stations is the sole source of information, at least one monitoring station should be kept. If, in zones where there is supplementary assessment, the result of this is that a zone has no remaining station, coordination with the number of stations in neighbouring zones must ensure adequate assessment of ozone concentrations against long-term objectives. The number of rural background stations should be 1 per 100 000 km<sup>2</sup>.

Source: Council Directive 2002/3/EC

Article 9

## Assessment of concentrations of ozone and precursor substances in ambient air

1. In zones and agglomerations where, during any of the previous five years of measurement, concentrations of ozone have exceeded a long-term objective, fixed continuous measurement is mandatory.

Where fewer than five years' data are available, Member States may, to determine exceedences, combine measurement campaigns of short duration at times and locations likely to be typical of the highest pollution levels with results obtained from emission inventories and modelling.

Annex IV sets out criteria for determining the location of sampling points for the measurement of ozone.

Section I of Annex V sets out the minimum number of fixed sampling points for continuous measurement of ozone in each zone or agglomeration within which measurement is the sole source of information for assessing air quality.

Measurements of nitrogen dioxide shall also be made at a minimum of 50% of the ozone sampling points required by Section I of Annex V. Measurement of nitrogen dioxide shall be continuous, except at rural background stations, as defined in section I of Annex IV, where other measurement methods may be used.

For zones and agglomerations within which information from sampling points for fixed measurement is supplemented by information from modelling and/or indicative measurement, the total number of sampling points specified in Section I of Annex V may be reduced, provided that:

- (a) the supplementary methods provide an adequate level of information for the assessment of air quality with regard to target values, information and alert thresholds;
- (b) the number of sampling points to be installed and the spatial resolution of other techniques are sufficient for the concentration of ozone to be established in accordance with the data quality objectives specified in Section I of Annex VII and lead to assessment results as specified in Section II of Annex VII;
- (c) the number of sampling points in each zone or agglomeration amounts to at least one sampling point per two million inhabitants or one sampling point per 50,000 km<sup>2</sup>, whichever produces the greater number of sampling points;
- (d) each zone or agglomeration contains at least one sampling point; and
- (e) nitrogen dioxide is measured at all remaining sampling points except at rural background stations.

In this case, the results of modelling and/or indicative measurement shall be taken into account for the assessment of air quality with respect to the target values.

2. In zones and agglomerations where, during each of the previous five years of measurement, concentrations are below the long-term objectives, the number of continuous measurement stations shall be determined in accordance with Section II of Annex V.
3. Each Member State shall ensure that at least one measuring station to supply data on concentrations of the ozone precursor substances listed in Annex VI is installed and operated in its territory. Each Member State shall choose the number and siting of the stations at which ozone precursor substances are to be measured, taking into account the objectives, methods and recommendations laid down in the said Annex.

As part of the guidance developed under Article 12, guidelines for an appropriate strategy to measure ozone precursor substances shall be laid down, taking into account existing requirements in Community legislation and the co-operative programme for monitoring and evaluation of the long-range transmission of air pollutants in Europe (EMEP).

4. Reference methods for analysis of ozone are set out in Section I of Annex VIII. Section II of Annex VIII provides for reference modelling techniques for ozone.
6. Any amendments necessary to adapt this Article and Annexes IV to VIII to scientific and technical progress shall be adopted in accordance with the procedure laid down in Article 13(2).

Source: Council Directive 2002/3/EC

# **Appendix 4**

## **Comparison of measured and modelled exceedence statistics**

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Table A1 Identified exceedences of the long-term objective for the protection of vegetation based upon measured data (1997-2001) and modelled data (2001 only) for background monitoring stations in UK zones.

Site	Zone	Measured AOT40 ( $\mu\text{g m}^{-3}\cdot\text{h}$ )					Mean AOT40 ( $\mu\text{g m}^{-3}\cdot\text{h}$ )	Modelled AOT40 ( $\mu\text{g m}^{-3}\cdot\text{h}$ )	Exceedence of Long-term objective category in 2001		
		1997	1998	1999	2000	2001	1997-2001	2001	Measured	Modelled*	Article 5**
Bottesford	East Midlands	3762	2134	5780	4298	8136	4822	9038	Yes	Yes	Yes
Ladybower	East Midlands	6636	3228	6012	2728	886	3898	5871	No	No	Yes
Sibton	Eastern	7572	4836	6340	3992	5604	5669	6151	No	Yes	Yes
Thurrock	Eastern	4082	2824	7484	3800	7668	5172	10666	Yes	Yes	Yes
Weybourne	Eastern					6356	6356	6901	Yes	Yes	Yes
Glazebury	North West & Merseyside	4182	2380	2944	3562	3012	3216	3577	No	No	No
Great Dun Fell	North West & Merseyside				4950	8264	6607	5339	Yes	No	Yes
Harwell	South East	9422	4394	9156	4464	7582	7004	9212	Yes	Yes	Yes
Lullington Heath	South East	9492	7432	11642	6264	10626	9091	11656	Yes	Yes	Yes
Rochester	South East	8984	5200	9782	4978	9854	7760	10571	Yes	Yes	Yes
Plymouth Centre	South West		3346	3068	2182		2865	7609	N/A	Yes	Yes
Somerton	South West	8854	7756	9992	8094	8090	8557	9014	Yes	Yes	Yes
Yarner Wood	South West	6178	6360	<b>10420</b>	4544	7582	7017	8422	Yes	Yes	Yes
Leamington Spa	West Midlands	3320	2712	5772	5262	5542	4522	8475	No	Yes	Yes
Wicken Fen	Eastern		3124	8050	4288	8680	6036	9658	Yes	Yes	Yes
Barnsley Gawber	Yorkshire & Humberside		1602	5898	3736	7372	4652	5667	Yes	No	Yes
High Muffles	Yorkshire & Humberside	5234	4736	7114	6432	7328	6169	7183	Yes	Yes	Yes
Aston Hill	North Wales	5706	3762	5738	4328	5218	4950	6330	No	Yes	Yes
Narberth	South Wales	6048	2196	5188	3846	5434	4542	6220	No	Yes	Yes
Derry	Northern Ireland	1436	332	1630	4136	826	1672	3016	No	No	No
Lough Navar	Northern Ireland	3118	868	2640	2904	3098	2526	3275	No	No	No
Eskdalemuir	Scottish Borders	4508	3276	5230	2390	2898	3660	3308	No	No	No
Bush Estate	Central Scotland	2478	1408	3214	1636	1960	2139	7680	No	Yes	Yes
Strath Vaich	Highland	4120	2146	7090	4018	2974	4070	5497	No	No	No

Absence of data indicates insufficient data available to calculate exceedence (data capture <75%)

\* indicates modelled annual average concentration at the location of the automatic monitor

\*\* indicates the exceedence statistic assigned to an agglomeration or zone as a whole, based on modelled or measured exceedences throughout the agglomeration or non-agglomeration zone

Table A2 Identified exceedences of the long-term objective for the protection of human health based upon measured data (1999-2001) and modelled data (2001 only) for monitoring stations in UK non-agglomeration zones.

Site	Zone	Measured days >120 $\mu\text{g m}^{-3}$			Mean days >120 $\mu\text{g m}^{-3}$	Modelled days >120 $\mu\text{g m}^{-3}$	Exceedence of Long-term objective category in 2001		
		1999	2000	2001	1999-2001	2001	Measured	Modelled*	Article 5**
Lough Navar	Northern Ireland	0	2	3	2	3	Yes	Yes	Yes
Bush Estate	Central Scotland	1	0	1	1	1	Yes	Yes	Yes
Plymouth Centre	South West	1	1		1	6	N/A	Yes	Yes
Derry	Northern Ireland	3	0	0	1	2	N/A	Yes	Yes
Sibton	Eastern	5	1	8	5	7	Yes	Yes	Yes
Glazebury	North West & Merseyside	6	1	2	3	1	Yes	Yes	Yes
Eskdalemuir	Scottish Borders	9	0	1	3	1	Yes	Yes	Yes
Strath Vaich	Highland	9	2		6	2	N/A	Yes	Yes
Narberth	South Wales	10		3	7	3	Yes	Yes	Yes
Barnsley Gawber	Yorkshire & Humberside	11	5	11	9	3	Yes	Yes	Yes
Leamington Spa	West Midlands	11	5	8	8	5	Yes	Yes	Yes
Wicken Fen	Eastern	11	4	11	9	9	Yes	Yes	Yes
Bottesford	East Midlands	12	3	9	8	7	Yes	Yes	Yes
Thurrock	Eastern	12	2	9	8	6	Yes	Yes	Yes
High Muffles	Yorkshire & Humberside	13	4	7	8	7	Yes	Yes	Yes
Rochester	South East	13	3	11	9	9	Yes	Yes	Yes
Aston Hill	North Wales	14	5	7	9	6	Yes	Yes	Yes
Ladybower	East Midlands	14	3		9	3	N/A	Yes	Yes
Somerton	South West	14	7	6	9	5	Yes	Yes	Yes
Harwell	South East	16	3	6	8	5	Yes	Yes	Yes
Lullington Heath	South East	16	9	15	13	13	Yes	Yes	Yes
Yarner Wood	South West	20	6	8	11	7	Yes	Yes	Yes
Norwich Centre	Eastern	23	5	8	12	6	Yes	Yes	Yes
Great Dun Fell	North West & Merseyside			12	12	11	Yes	Yes	Yes

Absence of data indicates insufficient data available to calculate formal exceedence (data capture <90%)

\* indicates modelled annual average concentration at the location of the automatic monitor

\*\* indicates the exceedence statistic assigned to an agglomeration or zone as a whole, based on modelled or measured exceedences throughout the agglomeration or zone

Table A2 Identified exceedences of the long-term objective for the protection of human health based upon measured data (1999-2001) and modelled data (2001 only) for monitoring stations in UK agglomeration zones.

Site	Zone	Measured days >120 $\mu\text{gm}^{-3}$			Mean days >120 $\mu\text{gm}^{-3}$	Modelled days >120 $\mu\text{gm}^{-3}$	Exceedence of Long-term objective category in 2001		
		1999	2000	2001	1997-2001	2001	Measured	Modelled*	Article 5**
Edinburgh Centre	Edinburgh Urban Area	0	0	0	0	1	No	Yes	Yes
Glasgow Centre	Glasgow Urban Area	0	0	0	0	0	No	Yes	Yes
London Lewisham	Greater London Urban Area	0			0	6	N/A	Yes	Yes
London Bloomsbury	Greater London Urban Area	1	0	1	1	2	Yes	Yes	Yes
Sheffield Centre	Sheffield Urban Area	1	1	1	1	2	Yes	Yes	Yes
Bristol Centre	Bristol Urban Area	2	0	1	1	3	Yes	Yes	Yes
London Hackney	Greater London Urban Area	2	0		1	5	N/A	Yes	Yes
London Hillingdon	Greater London Urban Area	2	0	2	1	4	Yes	Yes	Yes
Southampton Centre	Southampton Urban Area	2	0	2	1	5	Yes	Yes	Yes
Wolverhampton Centre	West Midlands Urban Area	2	1	3	2	4	Yes	Yes	Yes
Belfast Centre	Belfast Urban Area	3	1	2	2	2	Yes	Yes	Yes
Bradford Centre	West Yorkshire Urban Area	3	0	0	1	4	No	Yes	Yes
London Wandsworth	Greater London Urban Area	3	0	2	2	5	Yes	Yes	Yes
Manchester Piccadilly	Greater Manchester Urban Area	3	0	0	1	1	No	Yes	Yes
Manchester South	Greater Manchester Urban Area	3	0	0	1	2	No	Yes	Yes
Newcastle Centre	Tyneside	3	1	0	1	5	No	Yes	Yes
Birmingham Centre	West Midlands Urban Area	4	0	4	3	3	Yes	Yes	Yes
Nottingham Centre	Nottingham Urban Area	4	1	1	2	3	Yes	Yes	Yes
Bolton	Greater Manchester Urban Area	5	3	2	3	1	Yes	Yes	Yes
London Southwark	Greater London Urban Area	5	0	4	3	4	Yes	Yes	Yes
Middlesbrough	Teesside Urban Area	5	4	2	4	5	Yes	Yes	Yes
Rotherham Centre	Sheffield Urban Area	5	2	4	4	3	Yes	Yes	Yes
Swansea	Swansea Urban Area	5	4	4	4	4	Yes	Yes	Yes
Leeds Centre	West Yorkshire Urban Area	6	1	0	2	3	No	Yes	Yes
Salford Eccles	Greater Manchester Urban Area	6	0	1	2	1	Yes	Yes	Yes
London N. Kensington	Greater London Urban Area	7	2	3	4	4	Yes	Yes	Yes
Redcar	Teesside Urban Area	8	5	2	5	6	Yes	Yes	Yes
Sandwell West Bromwich	West Midlands Urban Area	8	3	8	6	3	Yes	Yes	Yes
Stoke-on-Trent Centre	The Potteries	8	3	4	5	2	Yes	Yes	Yes

Site	Zone	Measured days >120 µgm <sup>-3</sup>			Mean days >120 µgm <sup>-3</sup>	Modelled days >120 µgm <sup>-3</sup>	Exceedence of Long-term objective category in 2001		
		1999	2000	2001	1997-2001	2001	Measured	Modelled*	Article 5**
Birmingham East	West Midlands Urban Area	9	0	7	5	4	Yes	Yes	Yes
London Eltham	Greater London Urban Area	9	2	5	5	7	Yes	Yes	Yes
Port Talbot	Swansea Urban Area	9	7	4	7	4	Yes	Yes	Yes
Cardiff Centre	Cardiff Urban Area	11	2	2	5	3	Yes	Yes	Yes
London Bexley	Greater London Urban Area	11	2	6	6	7	Yes	Yes	Yes
London Haringey	Greater London Urban Area	11	3	6	7	5	Yes	Yes	Yes
London Brent	Greater London Urban Area	13	8	10	10	5	Yes	Yes	Yes
Leicester Centre	Leicester Urban Area	14	2	7	8	3	Yes	Yes	Yes
London Teddington	Greater London Urban Area	18	6	13	12	6	Yes	Yes	Yes
Blackpool	Blackpool Urban Area			3	3	3	Yes	Yes	Yes
Coventry Memorial Park	Coventry/Bedworth			7	7	4	Yes	Yes	Yes
Preston	Preston Urban Area			6	6	2	Yes	Yes	Yes
Southend-on-Sea	Southend Urban Area			8	8	7	Yes	Yes	Yes
Wirral Tranmere	Birkenhead Urban Area			8	8	2	Yes	Yes	Yes

Absence of data indicates insufficient data available to calculate formal exceedence (data capture <90%)

\* indicates modelled annual average concentration at the location of the automatic monitor

\*\* indicates the exceedence statistic assigned to an agglomeration or zone as a whole, based on modelled or measured exceedences throughout the agglomeration or zone



# **Appendix 5**

## **Annex VI relating to monitoring of ozone precursors**

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## ANNEX VI

## MEASUREMENTS OF OZONE PRECURSOR SUBSTANCES

## Objectives

The main objectives of such measurements are to analyse any trend in ozone precursors, to check the efficiency of emission reduction strategies, to check the consistency of emission inventories and to help attribute emission sources to pollution concentration.

An additional aim is to support the understanding of ozone formation and precursor dispersion processes, as well as the application of photochemical models.

## Substances

Measurement of ozone precursor substances must include at least nitrogen oxides, and appropriate volatile organic compounds (VOC). A list of volatile organic compounds recommended for measurement is given below.

Ethane	1-Butene	Isoprene	Ethyl benzene
Ethylene	trans-2-Butene	n-Hexane	m+p-Xylene
Acetylene	cis-2-Butene	i-Hexane	o-Xylene
Propane	1,3-Butadiene	n-Heptane	1,2,4-Trimeth. benzene
Propene	n-Pentane	n-Octane	1,2,3-Trimeth. benzene
n-Butane	i-Pentane	i-Octane	1,3,5-Trimeth. benzene
i-Butane	1-Pentene	Benzene	Formaldehyde
	2-Pentene	Toluene	Total non-methane hydrocarbons

## Reference methods

The reference method specified in Directive 1999/30/CE<sup>(1)</sup> or in subsequent Community legislation will apply for nitrogen oxides.

Each Member State must inform the Commission of the methods it uses to sample and measure VOC. The Commission must carry out inter-comparison exercises as soon as possible and investigate the potential for defining reference methods for precursor sampling and measurement in order to improve the comparability and precision of measurements for the review of this Directive in accordance with Article 11.

## Siting

Measurements should be taken in particular in urban and suburban areas at any monitoring site set up in accordance with the requirements of Directive 96/62/EC and considered appropriate with regard to the above monitoring objectives.

<sup>(1)</sup> OJ L 163, 29.6.1999, p. 41.