

# ANGLIAN REGION State of the Environment Report - THE IPC PERSPECTIVE

APRIL 1997



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# ANGLIAN REGION

## State of the Environment Report

### - THE IPC PERSPECTIVE

We have prepared this report to provide information and help contribute to discussion and development of policy on air quality.

We believe the information contained within this report will be extremely helpful and will support initiatives such as the Local Environment Agency Plans, help Local Authorities with their responsibilities under The United Kingdom National Air Quality Strategy as well as providing useful information on the state of the environment generally,

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April 1997

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# 1. INTRODUCTION

## 1.1 APPLICATIONS OF THIS INFORMATION

The objective of this report is to provide data examples to demonstrate:-

- the ambient air quality in Anglian Region of the Environment Agency;
- the air emissions from IPC processes;
- the mechanism of emission limiting by the IPC regulatory system.

These data will support initiatives such as Local Environment Agency Plans [LEAPs], Local Air Quality Strategies and effective communication within the functions of the Agency.

## 1.2 DATA SOURCES

The data presented in this report are derived from the Department of Environment's Air Quality Monitoring Network, in the case of ambient air quality, and the Environment Agency's Chemical Release Inventory [CRI]. The former data has been provided under contract, by NETCEN [AEA Technology plc]. Information on critical loads and acid deposition have been provided by the Mapping and Data Centre (MADC) at the Institute of Terrestrial Ecology (ITE).

## 1.3 LIMITATIONS

The ambient air quality maps are based on interpolation of data from a network of monitoring stations. The grid square air quality data produced takes account of urban, rural and major road factors, but local industrial sources are not accounted for.

The CRI is a major National database which contains a large amount of data, originating from the date of commencement of the system of Integrated Pollution Control under the Environmental Protection Act 1990. The data presented in this report is necessarily a small sample of that available from the CRI.

# 2. ANGLIAN REGION AMBIENT AIR QUALITY

## 2.1 INTRODUCTION

Information on local air quality is important in developing and implementing policy on the National Air Quality Strategy, Local Environment Agency Action Plans (LEAPs) and as a basis for Regional State of the Environment Reporting. In order to meet these different requirements, data on ambient air quality needs to be capable of being evaluated over differing time averaging periods and geographical scales, for example hourly or annual periods and regional, area or local levels. In practice the extent to which this can be achieved will depend on the presence and characteristics of monitoring stations. It is also important that the information used is consistent and has been properly quality assured.

The information presented in this report can be used as the basis for developing and implementing policy on a number of air quality issues.

All of the data included in this report have been fully quality assured. Information is only included where a full year of ratified data are available. For maps and site specific air quality measurements, data are provided for the most recent year for which a full ratified dataset is available. The quality assurance methods applied to the different datasets are described in the site specific air quality measurements section. The magnitude of the uncertainties in measured and interpolated values are discussed where appropriate.

## 2.2 OVERVIEW OF AIR QUALITY MAPS

### 2.2.1 INTRODUCTION

Since ambient pollutant concentrations often vary on a fine spatial scale, any attempt to map concentrations across the UK by direct interpolation of monitoring data will be subject to systematic interpolation errors. To overcome these difficulties, the correlation between concentrations and emissions-related parameters, for which data are available on a fine spatial scale, has been used to produce high resolution maps.

A mathematically straightforward, multi-stage approach has been adopted:



- Data from monitoring sites representative of rural concentrations can be interpolated to produce a map of rural concentrations.
- The impact of local scale (<20 km) emissions of pollutants on ambient concentrations can then be estimated using an empirical box modelling approach. These models can be calibrated using the relationships between measured concentrations and the values of surrogate statistics, such as emission intensity.

Details of the derivation and validation of the mapping procedures used are given in reports prepared for the DoE (Stedman *et al*, 1997a and 1997b). A general description of the mapping methods and key information about each map, including the sources of the datasets used, are provided here. All of the maps calculated for DoE provide estimates of air quality for the whole of the UK. In the maps presented here we have 'zoomed in' to show the Anglian Region in detail. The maps include a data acknowledgement and a brief summary of the sources of the monitoring data.

## 2.2.2 MONITORING NETWORK SITES

The mapping work described in this report makes use of data from many of the Department of the Environment Air Quality Monitoring Networks (see Bower *et al*, 1996 and references therein). Data from monitoring sites in the following networks were used:

Automatic Urban Monitoring Network (AUN)      Automatic Rural Monitoring Network (RMN)  
Automatic Hydrocarbon Monitoring Network (HMN)      Acid Deposition Secondary Network (ADSN)  
Rural Sulphur Dioxide Monitoring Network (RSO2N)      UK Nitrogen Dioxide Monitoring Network (NO2N)  
UK Smoke and Sulphur Dioxide Monitoring Networks, Basic Urban Network (BUN)

Data from monitoring sites within the Joint Environment Programme of National Power and PowerGen (JEP) have also been made available and were used in this work. The sites from the AUN, RMN, JEP, ADSN and HMN that were used in the mapping are listed in the Table 1.

**TABLE 1. THE LOCATIONS OF THE AIR QUALITY MONITORING SITES USED IN THE MAPPING WORK**

ID	Site Name	Site Type	Network	Easting	northing
1	Stevenage	Suburban	AUN	5237	2225
2	Cromwell Road	Kerbside	AUN	5264	1789
3	Sibton	Rural	RMN	6364	2719
4	West London	Urban Background	AUN	5251	1788
5	Glasgow City Chambers	Urban Background	AUN	2595	6653
6	Manchester Town Hall	Urban Background	AUN	3839	3979
7	Walsall	Urban Industrial	AUN	3994	2982
8	Billingham	Urban Industrial	AUN	4470	5237
9	Sheffield Tinsley	Urban Industrial	AUN	4402	3906
10	Bridge Place	Urban Background	AUN	5291	1790
11	Aston Hill	Rural	RMN	3298	2901
12	Lullington Heath	Rural	RMN	5538	1016
13	Strath Vaich	Rural	RMN	2347	8750
14	High Muffles	Rural	RMN	4776	4939
15	Lough Navar	Rural	RMN	192	5212
16	Yarner Wood	Rural	RMN	2786	789
17	Ladybower	Rural	RMN	4164	3892
18	Harwell	Rural	RMN	4474	1863
19	Bottesford	Rural	RMN	4797	3376
20	Bush	Rural	RMN	3245	6635
21	Eskdalemuir	Rural	RMN	3235	6028
22	Great Dun Fell	Rural	RMN	3711	5322
23	Wharleycroft	Rural	RMN	3698	5247
24	Glazebury	Rural	RMN	3690	3959
25	London Bloomsbury	Urban Centre	AUN	5302	1820
26	Edinburgh Centre	Urban Centre	AUN	3254	6738
27	Cardiff Centre	Urban Centre	AUN	3184	1765
28	Belfast Centre	Urban Centre	AUN	1475	5300
29	Birmingham Centre	Urban Centre	AUN	4064	2868
30	Newcastle Centre	Urban Centre	AUN	4251	5649
31	Leeds Centre	Urban Centre	AUN	4299	4343
32	Bristol Centre	Urban Centre	AUN	3594	1732
33	Liverpool Centre	Urban Centre	AUN	3349	3908

ID	Site Name	Site Type	Network	Easting	northing
34	Birmingham East	Urban Background	AUN	4116	2889
35	Hull Centre	Urban Centre	AUN	5097	4288
36	Leicester Centre	Urban Centre	AUN	4587	3040
37	Southampton Centre	Urban Centre	AUN	4429	1121
38	Bexley	Suburban	AUN	5518	1763
39	Swansea	Urban Centre	AUN	2655	1931
40	Middlesbrough	Urban Background	AUN	4505	5194
41	Bexieyheath	Suburban	JEP	5483	1745
42	Fleet Hall	Rural	JEP	5895	1893
43	Hall Farm	Rural	JEP	5589	1848
44	Lower Shorne	Rural	JEP	5703	1728
45	Wingham	Rural	JEP	6243	1553
46	Wormdale	Rural	JEP	5858	1634
47	Carr Lane	Rural	JEP	4672	4274
48	Hemmingbrough	Rural	JEP	4669	4298
49	Cliffe	Rural	JEP	4659	4336
50	North Duffield	Rural	JEP	4672	4373
51	Wheldrake	Rural	JEP	4690	4448
52	Dunnington	Rural	JEP	4674	4523
53	Eskdalemuir	Rural	ADSN	3235	6030
54	Goonhilly	Rural	ADSN	1723	214
55	Stoke Ferry	Rural	ADSN	5700	2988
56	Lough Navar	Rural	ADSN	192	5212
57	Barcombe Mills	Rural	ADSN	5437	1149
58	Yarner Wood	Rural	ADSN	2786	789
59	High Muffles	Rural	ADSN	4776	4939
60	Strathvaich Dam	Rural	ADSN	2347	8750
61	Glen Dye	Rural	ADSN	3642	7864
62	Preston Montford	Rural	ADSN	3432	3143
63	Flatford Mill	Rural	ADSN	6077	2333
64	River Mharcaidh	Rural	ADSN	2876	8052
65	Whiteadder	Rural	ADSN	3664	6633
66	Loch Dee	Rural	ADSN	2468	5779
67	Redesdale	Rural	ADSN	3833	5954
68	Bannisdale	Rural	ADSN	3515	5043
69	Cow Green Reservoir	Rural	ADSN	3817	5298
70	Thorganby	Rural	ADSN	4676	4428
71	Jenny Hurn	Rural	ADSN	4816	3986
72	Beddgelert	Rural	ADSN	2556	3518
73	Wardlow Hay Cop	Rural	ADSN	4177	3739
74	Bottesford	Rural	ADSN	4797	3376
75	Tycanol Wood	Rural	ADSN	2093	2364
76	Llyn Brienne	Rural	ADSN	2807	2492
77	Woburn	Rural	ADSN	4964	2361
78	Compton	Rural	ADSN	4512	1804
79	Driby	Rural	ADSN	5386	3744
80	Achanarras	Rural	ADSN	3151	9550
81	Hillsborough Forest	Rural	ADSN	1369	5156
82	Pumlumon	Rural	ADSN	2823	2854
83	Polloch	Rural	ADSN	1792	7689
84	Balquhiddy	Rural	ADSN	2521	7206
85	London UCL	Urban Roadside	HMN	5299	1822
86	London Eltham	Suburban	HMN	5440	1747
87	Edinburgh Med Sch	Urban Background	HMN	3257	6730
88	Belfast South	Urban Background	HMN	1470	5297
89	Cardiff East	Urban Background	HMN	3193	1773
90	Bristol East	Urban Background	HMN	3599	1729
91	Leeds Porternewton	Urban Background	HMN	4307	4367
92	Liverpool Speke	Urban Background	HMN	3438	3835

### 2.2.3 INTERPOLATION OF MEASUREMENT DATA FOR REGIONALLY REPRESENTATIVE SITES

Where data from appropriate measurement networks are available, maps of rural annual mean pollutant concentrations can be calculated by interpolation. Sites should be in rural areas away from significant local sources of pollutants such as major roads and urban areas and provide a reasonable coverage of the whole of the country. Such maps represent the spatial variation in concentrations across the UK for locations where the impact of sources within the distance range of about 0 to 20 km is small.

Maps of rural concentrations of NO<sub>2</sub>, SO<sub>2</sub> and O<sub>3</sub> can be calculated from measurements from the Acid Deposition Secondary Network, Rural Sulphur Dioxide Monitoring Network and Automatic Rural Monitoring Network respectively.

### 2.2.4 EMPIRICAL MODELLING OF LOCAL SOURCE CONTRIBUTION TO CONCENTRATIONS

In order to map pollutant concentrations where there are elevated concentrations due to the influence of local disperse emission sources (e.g. in urban areas or near major roads), a modelling approach is used. The mean concentration within an area of dispersed emission, such as an urban area, can be estimated using a simple box model. The mean concentration is dependent on the emissions intensity,  $q$ , the wind speed and the height through which the emissions disperse. The mean concentration,  $c$ , is given by

$$c = kq$$

Where  $k$  is an empirical constant, the value of which is dependent on mean wind speed and the height up to which pollutants emitted disperse (see section 2.2.6).

### 2.2.5 THE ORIGINS OF THE EMISSIONS ESTIMATES USED

Emissions estimates are currently available from the National Atmospheric Emissions Inventory (NAEI) at a 10 km x 10 km grid resolution (Salway *et al*, 1996). Background concentrations of pollutants such as NO<sub>x</sub> and NO<sub>2</sub> vary at a finer spatial scale than this. We have, therefore, used NO<sub>x</sub> emissions from major roads and the percentage of urban + suburban land cover, rather than published emissions estimates in the empirical modelling of the local contribution to ambient concentrations of NO<sub>x</sub> and NO<sub>2</sub> since data these data are available at 1 km x 1 km resolution (Fuller *et al*, 1994). Reliable alternative geographically based statistics for the estimation of emissions of pollutants such as SO<sub>2</sub>, at a spatial scale of finer than a 10 km x 10 km grid are not currently available and estimates from the NAEI at this resolution have, therefore, been used for SO<sub>2</sub>.

### 2.2.6 THE CALIBRATION OF THE EMPIRICAL MODELS USING MONITORING DATA

The empirical constant,  $k$ , for the relationship between the local contribution to ambient pollutant concentrations and local emissions can be derived as follows. The difference between the underlying rural concentration map and the automatic (or non-automatic) measurement values for each site is calculated where measurements are available. This difference can then be used as the dependent variable in a regression analysis with the emission estimates or surrogates for emissions estimates, as the independent variables to find a value for the coefficient  $k$ .

### 2.2.7 USING THE RELATIONSHIP BETWEEN THE CONCENTRATIONS OF TWO POLLUTANTS

An alternative approach has been adopted for pollutants such as benzene, 1,3-butadiene and CO, for which a map of rural concentrations cannot be calculated due to the lack of a comprehensive rural monitoring network. Maps of estimated annual mean concentrations of these pollutants have been calculated from the map of estimated NO<sub>x</sub> concentrations based on an analysis of the relationships between measured annual mean concentrations of these pollutants and measured annual mean NO<sub>x</sub> concentrations.

### 2.2.8 SPATIAL RESOLUTION OF THE MAPS

The maps presented here are at a range of spatial resolutions from 1 km x 1 km to 10 km x 10 km depending on the resolution of the input data available. All of the maps are presented in µg·m<sup>-3</sup> (or ng·m<sup>-3</sup>) for easy comparison with the site specific air quality measurement data presented in section 2.5. Several of the maps were originally calculated in ppb and for these maps the regression equations and validation statistics are presented in ppb. The conversion factors used are listed in section 4.



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## 2.3 AIR QUALITY MAPS OF INDIVIDUAL POLLUTANTS

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### 2.3.1 OZONE

The map of estimated summer mean ozone concentration presented here were developed in conjunction with the Institute of Terrestrial Ecology at Bush. The methods of mapping ozone concentrations are discussed in detail in the 4th report of the Photochemical Oxidants Review Group (PORC, 1996). Mean values of the ozone statistics for the period 1990 to 1994 inclusive were calculated by PORC to take into account the large year to year variation in ozone episode frequency due to meteorological variability.

The ozone monitoring sites within the RMN are at a range of elevations. Mean ozone concentrations vary with altitude due to the more efficient removal of ozone at night in sheltered lowland areas than at more exposed higher altitude areas (PORC, 1993). Mean ozone concentrations during the middle part of the day (12-18 GMT) are not influenced by altitude due to the more efficient mixing of air at different heights during this period. Mean ozone concentrations at RMN sites during this 'well mixed' period can, therefore, be interpolated to produce a map of summer mean ozone concentration for the well mixed part of the day. The difference between concentrations during this well mixed period and the mean over the whole day ( $\Delta O_3$ ) has been found to be dependent on altitude:

$$O_3 = 3.4 + 7.7e^{-4.2 \times 10^{-3} \cdot \text{altitude}}$$

where the altitude is in meters (m) for the 1 km x 1 km grid square including the site location. A map of rural summer mean ozone concentrations can, therefore, be calculated from the 'well mixed map' and an altitude map of the UK using the above equation.

Mean ozone concentrations in urban areas are generally lower than in the surrounding countryside due to the reaction of ozone with primary NO emissions. These primary NO emissions are mainly from traffic sources. The percentage of urban + suburban land cover in each 5 km x 5 km grid square can be assumed to be proportional to the magnitude of  $NO_x$  emissions (which is mostly NO). Land cover information can therefore be used to superimpose the depleting effect of urban areas on summer mean ozone concentrations using the following relationship:

$$\text{summer\_mean\_}O_3 = \text{rural\_summer\_mean\_}O_3 \cdot (0.45 + 0.55 \cdot ((100 - \text{us25km})/100))$$

where

**summer\_mean\_** $O_3$  is the estimated summer mean background ozone concentration for the years 1990-94 for the 5 km x 5 km grid square (ppb);

**rural\_summer\_mean\_** $O_3$  is the map of rural summer mean ozone concentrations calculated from measurements at rural monitoring sites and adjusted for altitude effects;

**us25km** is the mean percentage of (urban + suburban) land cover for an area of 25 km<sup>2</sup> centred at the estimation location.

There is good agreement between the estimated summer mean ozone concentrations for 1990-94 and measured values (mean of measurements = 24.2 ppb, mean of estimates at these locations = 23.1 ppb,  $r = 0.92$ , number of sites,  $n = 30$  ).

The data acknowledgement for this map is DoE/ITE/NETCEN.

### 2.3.2 NITROGEN DIOXIDE

A 1 km x 1 km grid square map of estimated annual mean background  $NO_2$  concentrations for 1994 is presented. This map was calculated from map of rural  $NO_2$  concentrations; the local source contribution was estimated from the surrogate datasets of  $NO_x$  emissions from major roads and land cover statistics. The empirical model of the relationship between these surrogate statistics and urban  $NO_2$  concentrations was calibrated using automatic monitoring data.

The relationship used to calculate the map was:

$$\text{estimated\_}NO_2 = \text{rural\_}NO_2 + 0.1340 \cdot \text{us100km} + 0.0961 \cdot \text{us25km} + 0.0338 \cdot NO_x4km$$

where

**estimated\_** $NO_2$  is the estimated annual mean background  $NO_2$  concentration for 1994 for the 1 km x 1 km grid square (ppb)

**rural\_** $NO_2$  is the map interpolated from rural  $NO_2$  measurements by monthly diffusion tube at 32 ADSN sites (ppb);

<b>us25km</b>	is the mean percentage of (urban + suburban) land cover for an area of 25 km <sup>2</sup> centred at the estimation location;
<b>us100km</b>	is the mean percentage of (urban + suburban) land cover for an area of 100 km <sup>2</sup> centred at the estimation location;
<b>NO<sub>x</sub>4km</b>	is the total NO <sub>x</sub> emission from major road vehicle sources (tonnes per km <sup>2</sup> per year) within the 4 km <sup>2</sup> area surrounding the estimation location.

The agreement between the estimated and measured annual mean NO<sub>2</sub> concentrations for 1994 at the automatic monitoring sites was good (mean of measurements = 20.1 ppb, mean of estimates at these locations = 18.8 ppb,  $r = 0.93$ , number of sites,  $n = 37$ ). The mapping error at locations for which automatic measurements were not available is likely to be at least as large as the error at these monitoring sites, which were the ones used to calibrate the mapping procedure. The applicability of the NO<sub>2</sub> map to background locations has been further examined by comparison of estimated concentrations from the map with annual mean NO<sub>2</sub> concentrations for 1994 from over 500 'urban background' sites within the UK Nitrogen Dioxide Survey (Stevenson and Bush, 1996). Urban Background sites are defined in this network as being more than 50 m from any busy road and typically in a residential area. This dataset was not used in the calculation of the coefficients used to derive the map and is, therefore, valuable as a validation dataset. There is no evidence of a large systematic error in the estimates of annual mean background NO<sub>2</sub> concentration. The mean of the measured concentrations was 14.2 ppb; the mean of the estimated concentrations was 14.4 ppb;  $r = 0.60$ .

The data acknowledgement for this map is DoE/NETCEN.

### 2.3.3 NITROGEN OXIDES

A 1 km x 1 km grid square map of estimated annual mean background NO<sub>x</sub> concentrations for 1994 is presented. This map was calculated in the same way as the map of NO<sub>2</sub> concentrations. It was calculated from a map of rural NO<sub>2</sub> concentrations; the local source contribution was estimated from the surrogate datasets of NO<sub>x</sub> emissions from major roads and land cover statistics. The empirical model of the relationship between these surrogate statistics and measured urban NO<sub>x</sub> concentrations was calibrated using automatic monitoring data.

The relationship used to calculate the map was:

$$\text{estimated\_NO}_x = \text{rural\_NO}_x + 0.4320.\text{us25km} + 0.2061.\text{NO}_x4\text{km}$$

where

<b>estimated_NO<sub>x</sub></b>	is the estimated annual mean background NO <sub>x</sub> concentration for 1994 for the 1 km x 1 km grid square (ppb);
<b>rural_NO<sub>x</sub></b>	is the map interpolated from rural NO <sub>2</sub> measurements multiplied by 1.2; which is representative of the ratio between annual mean concentrations of NO <sub>x</sub> and NO <sub>2</sub> at rural automatic monitoring sites (ppb);
<b>us25km</b>	is the mean percentage of (urban + suburban) land cover for an area of 25 km <sup>2</sup> centred at the estimation location;
<b>NO<sub>x</sub>4km</b>	is the total NO <sub>x</sub> emission from major road vehicle sources (tonnes per km <sup>2</sup> ) within the 4 km <sup>2</sup> area surrounding the estimation location.

The agreement between the estimated and measured annual mean NO<sub>x</sub> concentrations for 1994 at the automatic monitoring sites was good (mean of measurements = 42.6 ppb, mean of estimates at these locations = 37.4 ppb,  $r = 0.93$ ,  $n = 37$ ). The mapping error at locations for which automatic measurements were not available is likely to be at least as large as the error at these monitoring sites, which were also used to calibrate the mapping procedure.

The data acknowledgement for this map is DoE/NETCEN.

### 2.3.4 LEAD

The 1 km x 1 km grid square resolution map of estimated annual mean airborne lead concentrations for 1994 was calculated from the map of NO<sub>x</sub> concentrations. The calculation was based on a regression analysis of the relationship between measured ambient annual mean NO<sub>x</sub> and lead concentrations at the urban background sites at Bridge Place and the urban kerbside site at Cromwell Road between 1990 and 1994.

The relationship used to calculate the map was:

$$\text{estimated\_lead} = 1.32.\text{estimated\_NO}_x$$

where

**estimated\_lead** is the estimated annual mean background lead concentration for 1994 for the 1 km x 1 km grid square ( $\text{ngm}^{-3}$ )

**estimated\_NO<sub>x</sub>** is the estimated annual mean background NO<sub>x</sub> concentration map value for 1994 for the 1 km x 1 km grid square (ppb)

The reliability of this map has been examined by comparison with urban and rural background measurements of lead from within the Multi-element, Lead in Petrol and AEAT rural monitoring networks for 1994. Agreement is good (mean of measurements =  $35.1 \text{ ngm}^{-3}$ , mean of estimates at these locations =  $37.0 \text{ ngm}^{-3}$ ,  $r = 0.89$ ,  $n = 12$ ). Data from these networks provide a valuable independent check in the validity of the map since measurements from only one of the sites were used to derive the relationship used. Background concentrations of lead in the UK are generally much lower than  $500 \text{ ngm}^{-3}$ , and are related to the intensity of emission from vehicles. The estimated map provides a good estimate of lead concentrations from these sources. Concentrations in the vicinity of significant industrial lead emission sources can be much higher and are not included in this map.

The data acknowledgement for this map is DoE/NETCEN.

### 2.3.5 CARBON MONOXIDE

The 1 km x 1 km grid square map of estimated annual mean carbon monoxide concentrations for 1994 was calculated from the map of NO<sub>x</sub> concentrations. The calculation was based on a regression analysis of the relationship between measured ambient annual mean background CO and NO<sub>x</sub> concentrations at AUN sites.

The relationship used to calculate the map was:

$$\text{estimated\_CO} = 11.3 \cdot \text{estimated\_NO}_x$$

where

**estimated\_CO** is the estimated annual mean background CO concentration for 1994 for the 1 km x 1 km grid square (ppb);

**estimated\_NO<sub>x</sub>** is the estimated annual mean background NO<sub>x</sub> concentration map value for 1994 for the 1 km x 1 km grid square (ppb)

Overall the agreement between the measured and estimated concentrations is poor (mean of measurements = 620 ppb, mean of estimates at these locations = 580 ppb,  $r = 0.10$ ,  $n = 20$ ). There are two reasons for the inaccuracy of these estimates:

- inaccuracies in the NO<sub>x</sub> map;
- site to site variations in CO to NO<sub>x</sub> ratio.

Agreement between estimated and measured concentrations is good for some sites such as Bridge Place, Leeds Centre, Hull Centre and Bexley. There are also a number of sites showing particularly poor agreement. In many cases this reflects variation in the ambient CO to NO<sub>x</sub> ratio due to type of road and distance from the road. The relative amounts of CO and NO<sub>x</sub> emitted from vehicles varies with speed, CO emissions are greatest from slow moving traffic, while NO<sub>x</sub> emissions are greatest for vehicles travelling at high speed. The mean value of the measured CO to NO<sub>x</sub> ratio at AUN sites in 1994 was 11.1 but ranged from 4.8 at Sheffield Tinsley to 17.1 at Cardiff Centre. The map does, however, provide the best available indication of the likely spatial variation of CO concentrations in the Anglian Region area in the absence of any national network automatic monitoring sites.

The data acknowledgement for this map is DoE/NETCEN.

### 2.3.6 SULPHUR DIOXIDE

A 10 km x 10 km grid square map of estimated annual mean background SO<sub>2</sub> concentrations for 1994 is presented. This map was calculated from a map of rural SO<sub>2</sub> concentrations; the local source contribution was estimated from SO<sub>2</sub> emissions estimates from area sources from the NAEI. The empirical model of the relationship between emissions and measured urban SO<sub>2</sub> concentrations was calibrated using data from BUN sites in large urban areas.

The spatial distribution of the dispersed emissions of NO<sub>x</sub> is closely related to the extent of urban areas. Land cover information can, therefore, be used as a surrogate variable for the magnitude of NO<sub>x</sub> emissions. This is not the case for SO<sub>2</sub> and estimates at the highest spatial resolution currently available from the NAEI have been used.

The spatial distribution of SO<sub>2</sub> emissions from disperse sources is reasonably well described within the 10 km x 10 km inventory, with the exception of areas with significant coal use for domestic heating. Coal is not widely used within the majority of large urban areas in GB and these large urban areas are well represented at this grid resolution. Significant coal use is generally restricted to the smaller towns and villages in Northern Britain, and the density of

SO<sub>2</sub> emissions within these small areas cannot be represented by a 10 km x 10 km average value. Land cover information cannot be used to simply assign the SO<sub>2</sub> emission estimates to urban areas because coal use is greater in the smaller urban areas. A regression analysis was, therefore, carried out using measured SO<sub>2</sub> concentrations for sites within the BUN for which at least 80% of the surrounding land cover in the 5 km x 5 km grid square was defined as urban or suburban. The difference between the underlying rural SO<sub>2</sub> concentration map and the measured ambient mean SO<sub>2</sub> concentration for the period 1992 to 1995 was calculated for these sites. This difference was then used as the dependent variable and an equation was obtained. The equation for the SO<sub>2</sub> map was:

$$\text{estimated\_SO}_2 = \text{rural\_SO}_2 + 0.001.\text{SO}_2100\text{km}$$

where

**estimated\_SO<sub>2</sub>** is the estimated annual mean background SO<sub>2</sub> concentration for 1994 for the 10 km x 10 km grid square (ppb);

**rural\_SO<sub>2</sub>** is the map interpolated from rural SO<sub>2</sub> measurements at a total of 51 RSO<sub>2</sub>N, RMN and JEP monitoring sites (Vincent and Campbell, 1996) (ppb);

**SO<sub>2</sub> 100km** is the area source emission estimate for the 100 km<sup>2</sup> grid square (tonnes per year).

The reliability of this map was assessed by comparison with data from automatic monitoring sites. This map provides good estimates of SO<sub>2</sub> concentrations in rural areas and in urban areas without significant coal use for domestic heating. SO<sub>2</sub> concentrations are underestimated in coal use areas. SO<sub>2</sub> concentrations in Belfast are seriously underestimated by the map; the agreement at the other automatic monitoring sites is much better (excluding Belfast: mean of measurements = 6.3 ppb, mean of estimates at these locations = 6.4 ppb,  $r = 0.78$ ,  $n = 35$ ). Automatic monitoring data provides an independent test of the reliability of the map, particularly in urban areas, because it was not used to calibrate empirical model.

The data acknowledgement for this map is DoE/NETCEN.

### 2.3.7 PM<sub>10</sub> PARTICLES

A 1 km x 1 km grid square resolution map of estimated annual mean particle (PM<sub>10</sub>) concentrations for 1994 is presented. Ambient annual mean particle concentrations in the UK include contributions from a range of sources, including:

- primary fine particles, emitted directly into the atmosphere as a result of combustion process (often from diesel vehicles);
- secondary fine particles formed in the atmosphere by the oxidation of oxides of sulphur and nitrogen (and often formed many 10s of km down wind of the emission source area);
- crustal material (which tends to include coarser particles).

The map presented here was calculated from estimates of contributions from these three sources. The contribution from primary particles was calculated from the estimated NO<sub>x</sub> map; the contribution from secondary particles was estimated from rural measurements of sulphate and nitrate particles and the contribution from crustal material was assumed to be constant across the country.

$$\text{estimated\_PM}_{10} = 0.15.\text{estimated\_NO}_x + \text{secondary\_PM}_{10} + 5.5$$

where

**estimated\_PM<sub>10</sub>** is the estimated annual mean background PM<sub>10</sub> concentration for 1994 for the 1 km x 1 km grid square (µgm<sup>-3</sup>);

**estimated\_NO<sub>x</sub>** is the estimated annual mean background NO<sub>x</sub> concentration map value for 1994 for the 1 km x 1 km grid square (ppb);

**secondary\_PM<sub>10</sub>** is a map of annual mean secondary PM<sub>10</sub> concentrations interpolated from values derived from measurements of particulate sulphate (8 sites) and nitrate (2 sites) (µgm<sup>-3</sup>).

This expression was derived from a regression analysis of the difference between the measured annual mean PM<sub>10</sub> concentrations at AUN sites and the estimated secondary particle concentration at each site and measured annual mean NO<sub>x</sub> concentrations. Overall, the agreement between estimated and measured concentrations is poor (mean of measurements = 24.1 µgm<sup>-3</sup>, mean of estimates at these locations = 22.2 µgm<sup>-3</sup>,  $r = 0.16$ ,  $n = 14$ ). The map correctly predicts that the highest and lowest concentrations are at London Bloomsbury and Edinburgh Centre respectively. The estimates are all in the correct region of 20 - 30 µgm<sup>-3</sup>, and there is also good agreement between the means of the measurements and estimates. The poor correlation shows that the accuracy of the estimates for the individual site locations is poor. This is due to a combination of the uncertainties associated with both the errors

introduced by estimating the PM<sub>10</sub> concentration from the maps of NO<sub>x</sub> and secondary particles and with the errors present in the map of estimated annual mean NO<sub>x</sub> concentration. The map does, however, provide the best available indication of the likely spatial variation of PM<sub>10</sub> concentrations in the Anglian Region area, particularly in the absence of any national network automatic monitoring sites.

The data acknowledgement for this map is DoE/NETCEN.

### 2.3.8 BENZENE

The 1 km x 1 km grid square map of estimated annual mean background benzene concentrations for 1994 presented here was calculated from the map of estimated NO<sub>x</sub> concentrations. The calculation was based on a regression analysis of the relationship between measured ambient daily mean benzene and NO<sub>x</sub> concentrations. Co-located automatic measurements for these two pollutants were available for one monitoring site during 1994 (Birmingham East). The validity of the regression coefficient obtained was confirmed by repeating the regression analysis for cities where benzene and NO<sub>x</sub> concentration measurements were made at sites separated by a few km.

In contrast to the NO<sub>2</sub> and SO<sub>2</sub> maps, A map of estimated benzene concentrations cannot be calculated directly from a combination of map of rural concentrations and surrogate statistics owing to the of the lack of an extensive monitoring network for benzene measurement in rural areas.

$$\text{estimated\_benzene} = 0.022.\text{estimated\_NO}_x + 0.202$$

where

**estimated\_benzene** is the estimated annual mean background benzene concentration for 1994 for the 1 km x 1 km grid square (ppb);

**estimated\_NO<sub>x</sub>** is the estimated annual mean background NO<sub>x</sub> concentration map value for 1994 for the 1 km x 1 km grid square (ppb).

There is reasonably good agreement between the estimated annual mean benzene concentrations for 1994 and measured annual mean benzene concentrations at HMN sites in 1995 (mean of measurements = 1.05 ppb, mean of estimates at these locations = 1.17 ppb,  $r = 0.55$ ,  $n = 12$ ). Measured data for 1995 was used in preference to that from 1994, due to the larger number of sites with available data. The assumption implicit in the calculation of this map of background benzene concentrations is that ambient benzene and NO<sub>x</sub> concentrations are influenced by a common dominant source: vehicle emissions. This is a reasonable assumption in most urban areas. Ambient concentrations of benzene and NO<sub>x</sub> in rural areas will be determined by a wider range source types and by the atmospheric lifetimes of these species. The estimates of rural concentrations presented in the map will therefore have a greater uncertainty than those in urban areas. Locations with significant non-traffic related emission sources of benzene will experience higher ambient concentrations than those presented here.

The data acknowledgement for this map is DoE/NETCEN.

### 2.3.9 1,3-BUTADIENE

The 1 km x 1 km grid square map of estimated annual mean background 1,3-butadiene concentrations for 1994 was calculated from the map of NO<sub>x</sub> concentrations using the same method as the map of estimated benzene concentrations. The calculation was based on a regression analysis of the relationship between measured ambient background 1,3-butadiene and NO<sub>x</sub> concentrations at the one monitoring site (Birmingham East) for which co-located automatic measurements for these two pollutants were available during 1994.

$$\text{estimated\_1,3-butadiene} = 0.0044.\text{estimated\_NO}_x + 0.0051$$

where

**estimated\_1,3-butadiene** is the estimated annual mean background 1,3-butadiene concentration for 1994 for the 1 km x 1 km grid square (ppb)

**estimated\_NO<sub>x</sub>** is the estimated annual mean background NO<sub>x</sub> concentration map value for 1994 for the 1 km x 1 km grid square (ppb)

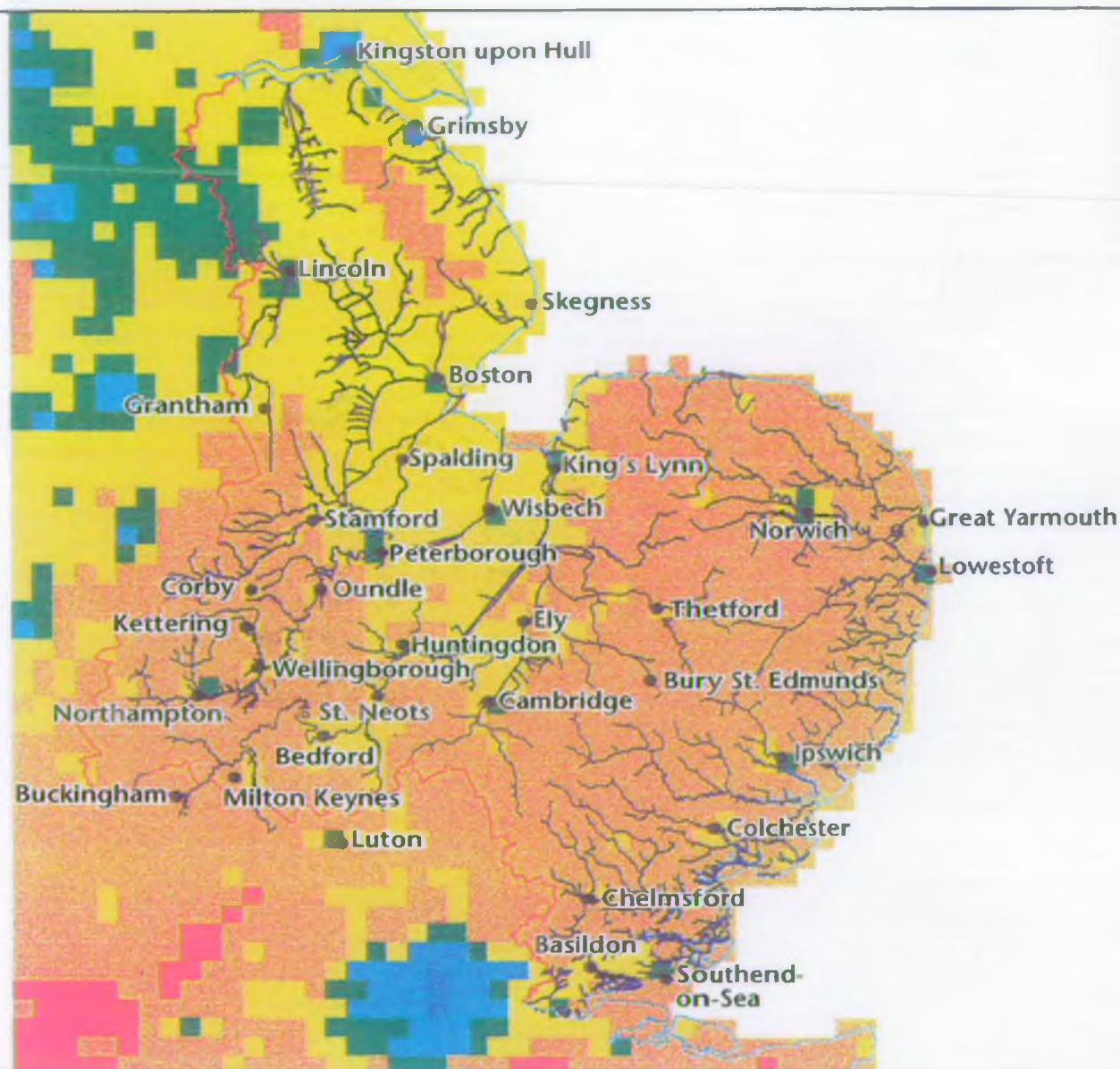
There is reasonably good agreement between the estimated annual mean 1,3-butadiene concentrations for 1994 and measured annual mean 1,3-butadiene concentrations at HMN sites in 1995 (mean of measurements = 0.22 ppb, mean of estimates at these locations = 0.20 ppb,  $r = 0.67$ ,  $n = 12$ ). Measured data for 1995 was used in preference to that from 1994, due to the larger number of sites in 1995. The reliability of these maps in rural areas or locations subject to significant influence from non-traffic related sources is limited in the same way as the map of benzene concentrations.

The data acknowledgement for this map is DoE/NETCEN.



# Estimated summer mean background ozone concentration, 1990-1994 ( $\mu\text{g}/\text{m}^3$ )

Ref NETCEN 14/02/96 16419002/JRS



Ozone summer mean,  $\mu\text{g}/\text{m}^3$



— Anglian Region Boundary      — Rivers      — Coastline

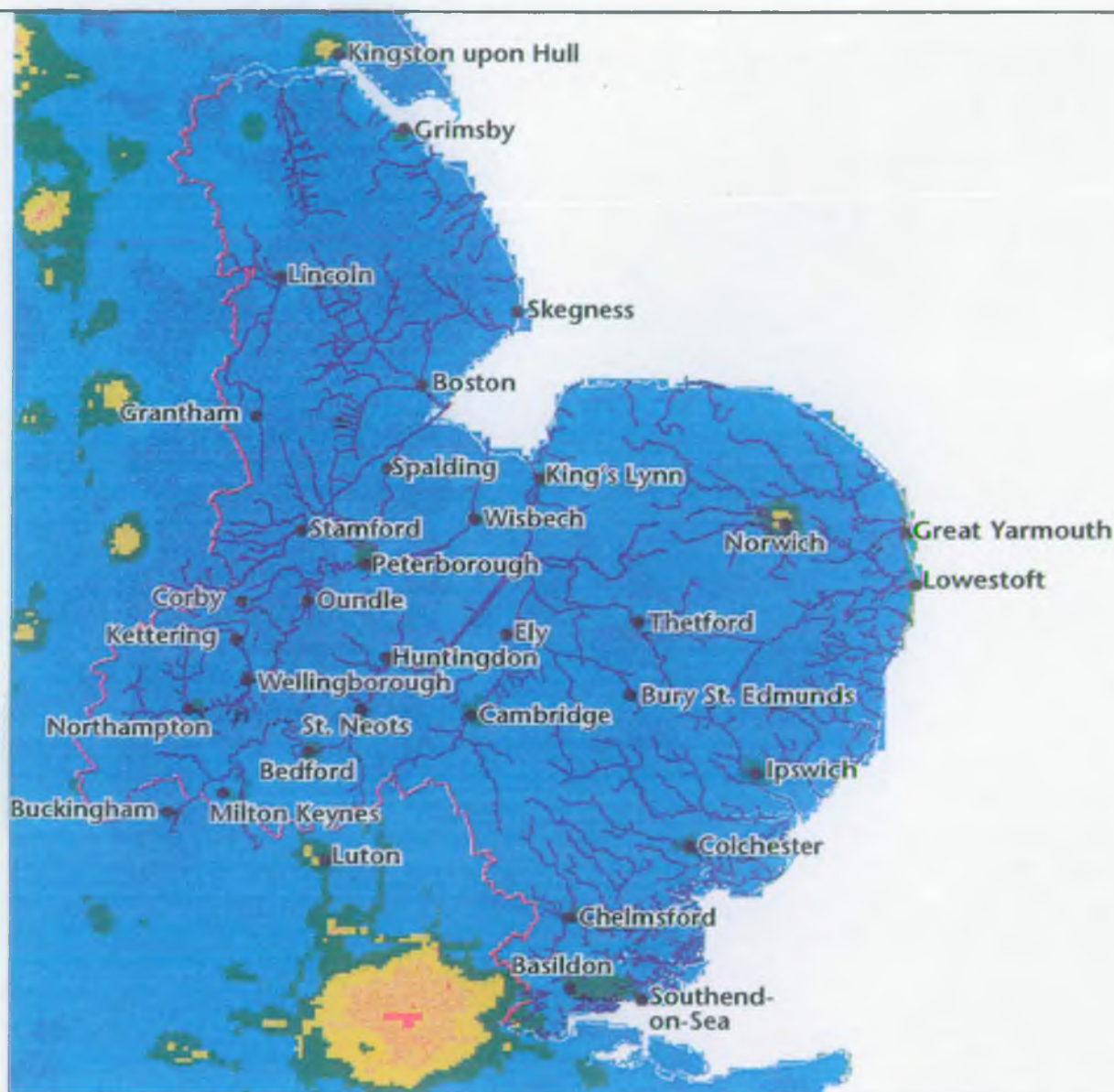
Data Acknowledgement: DoE/ITE/NETCEN

Incorporates monitoring data from: DoE Rural Monitoring Network and Automatic Monitoring Urban Network



# Estimated annual mean background nitrogen dioxide concentration, 1994 $\mu\text{g}/\text{m}^3$

Ref NETCEN 24/07/96 20008001/JRS UK1KM\_NO23



Nitrogen dioxide,  $\mu\text{g}/\text{m}^3$



Anglian Region Boundary    Rivers    Coastline

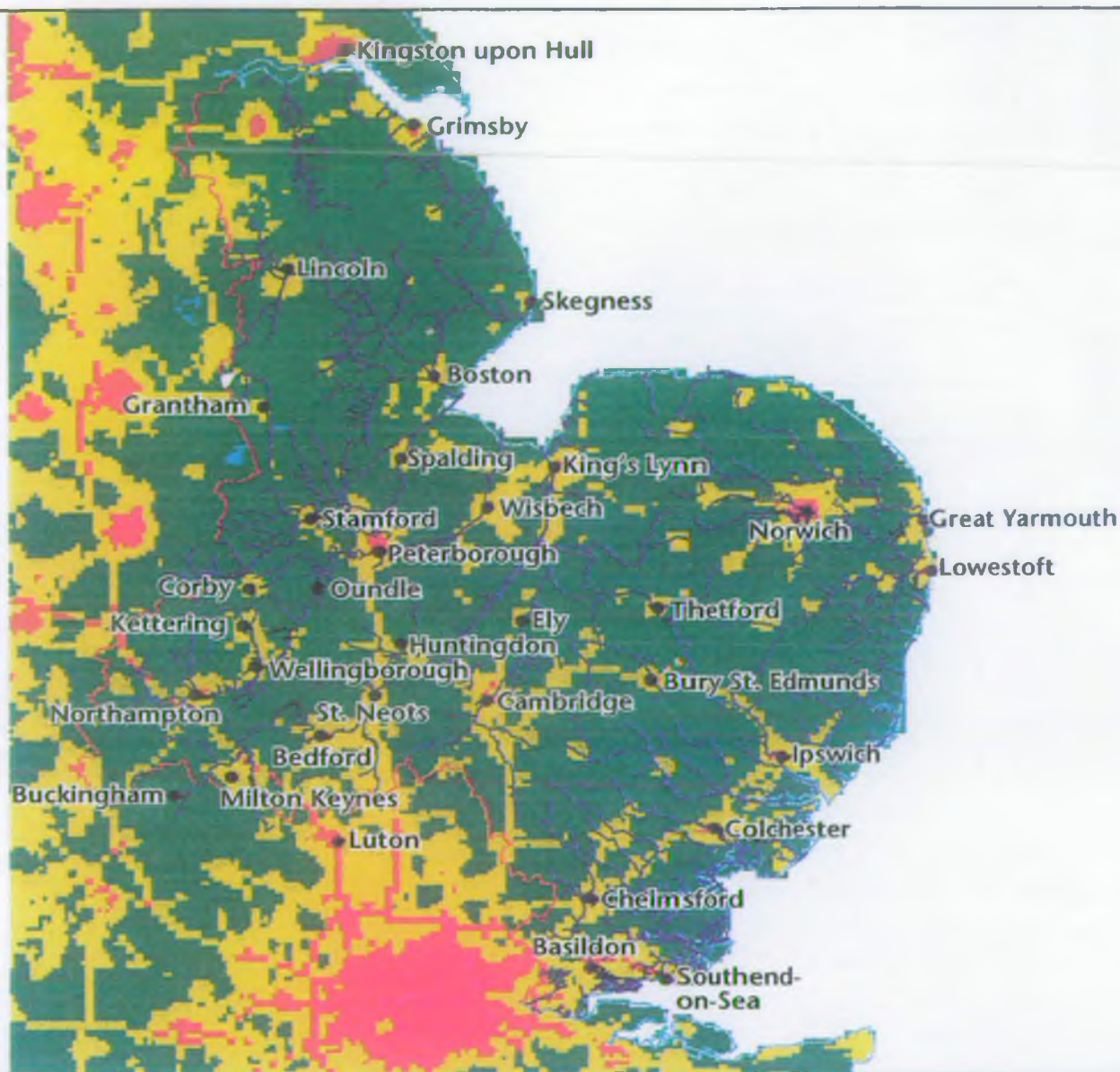
Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Rural Monitoring Network, Automatic Urban Network, Acid Deposition Network and Joint Environment Programme of National Power and PowerGen

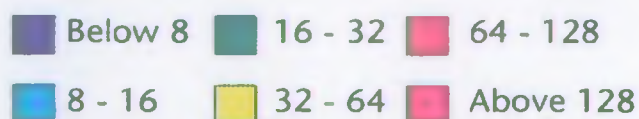


# Estimated annual mean background oxides of nitrogen concentration, 1994 ( $\mu\text{g}/\text{m}^3$ )

Ref NETCEN 24/07/96 20008001/JRS UK1KM\_NOX3



Oxides of nitrogen,  $\mu\text{g}/\text{m}^3$



— Anglian Region Boundary — Rivers — Coastline

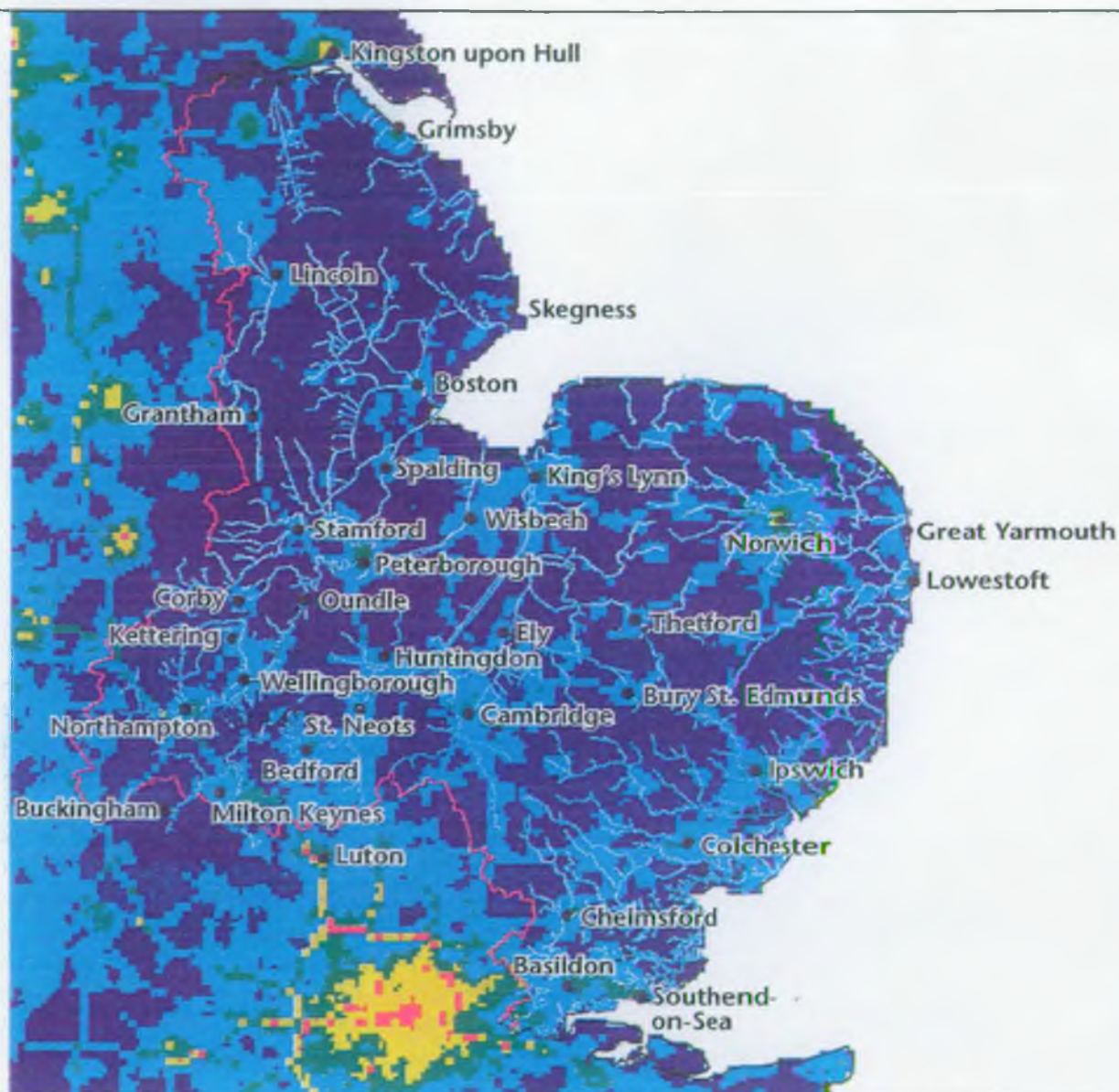
Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Rural Monitoring Network, Automatic Urban Network, Acid Deposition Network and Joint Environment Programme of National Power and PowerGen



# Estimated annual mean background carbon monoxide concentration, 1994 ( $\mu\text{g}/\text{m}^3$ )

Ref NETCEN 24/07/96 20008001/JRS UK1KM\_CO1



Carbon monoxide,  $\mu\text{g}/\text{m}^3$



Anglian Region Boundary

Rivers

Coastline

Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Automatic Urban Network



# Estimated annual mean background lead concentration, 1994 ( $\mu\text{g}/\text{m}^3$ )

Ref NETCEN 29/01/97 20008001/JRS UK1KM\_LEAD1



Lead  $\text{ng}/\text{m}^3$



— Anglian Region Boundary      — Rivers      — Coastline

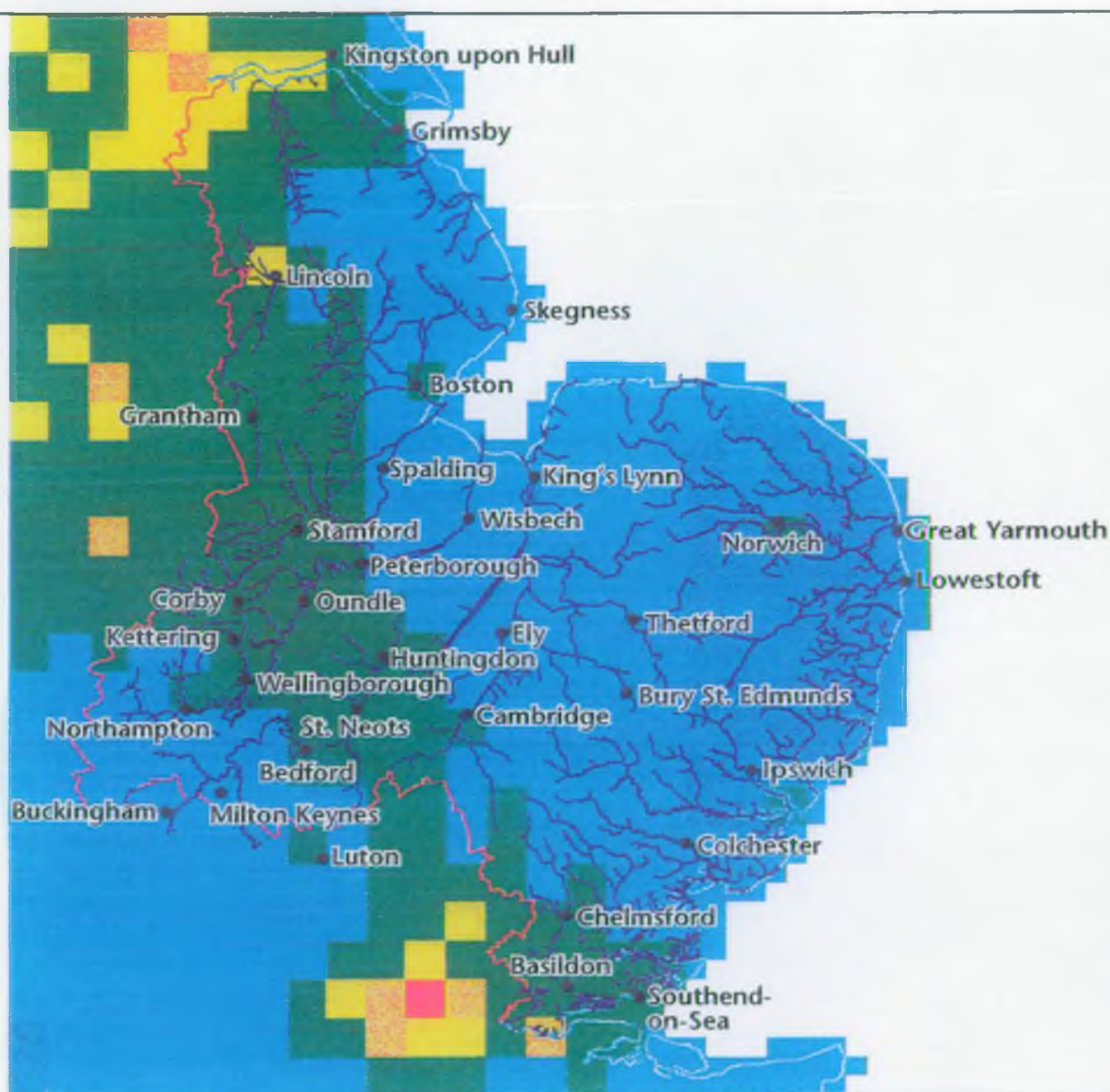
Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Lead in Petrol, Multi-element and AEAT Rural Networks



# Estimated annual mean background sulphur dioxide concentration, 1994 ( $\mu\text{g}/\text{m}^3$ )

Ref NETCEN 21/04/96 20008001/GWC



Sulphur Dioxide,  $\mu\text{g}/\text{m}^3$



Anglian Region Boundary

Rivers

Coastline

Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Rural Rural SO<sub>2</sub>, Rural Automatic and Smoke and SO<sub>2</sub> Networks, and Joint Environment Programme of National Power and PowerGen



# Estimated annual mean background PM10 concentration, 1994 ( $\mu\text{g}/\text{m}^3$ )

Ref NETCEN 18/11/96 20008001/JRS UK1KM\_PM101



PM10  $\mu\text{g}/\text{m}^3$



— Anglian Region Boundary

— Rivers

— Coastline

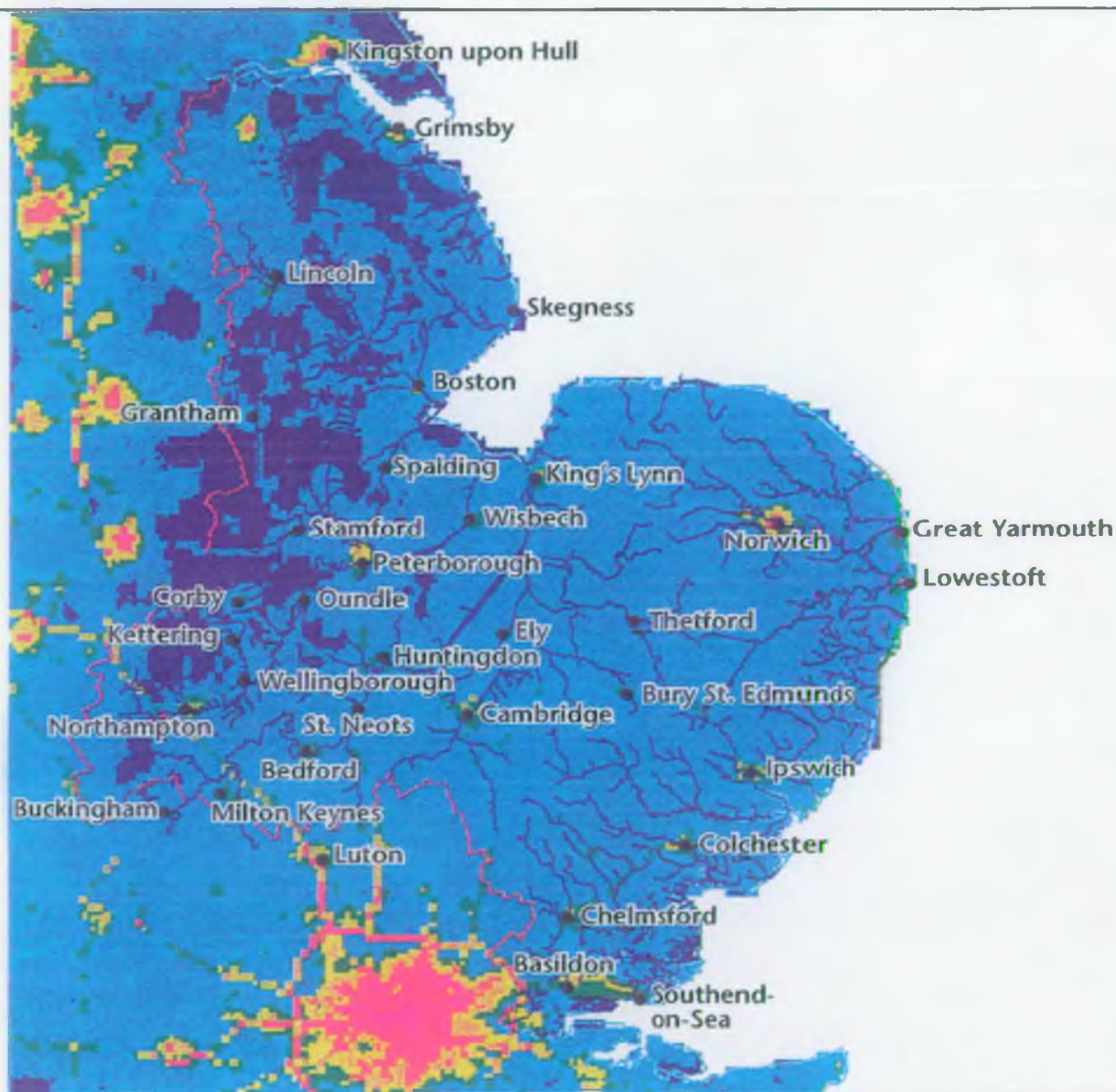
Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: Automatic Urban Network



# Estimated annual mean background benzene concentration, 1994 ( $\mu\text{g}/\text{m}^3$ )

Ref NETCEN 15/10/96 20008001/JRS UK1KM\_BZ1



Benzene  $\mu\text{g}/\text{m}^3$



Anglian Region Boundary      Rivers      Coastline

Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Automatic Hydrocarbon Network

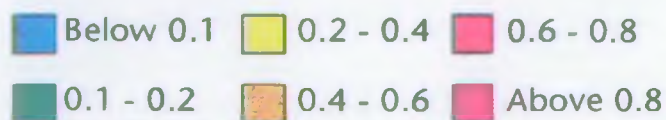


# Estimated annual mean background 1,3-butadiene concentration, 1994 (ug/m<sup>3</sup>)

Ref NETCEN 15/10/96 20008001/JRS UK1KM\_13BUT1



1,3-butadiene ug/m<sup>3</sup>



— Anglian Region Boundary      — Rivers      — Coastline

Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Automatic Hydrocarbon Network

## 2.4 AIR QUALITY CRITERIA EXCEEDANCE MAPS

### 2.4.1 AIR QUALITY CRITERIA EXCEEDANCE MAPS FOR OZONE

Two air quality criteria exceedance maps for ozone are presented:

- A 5 km x 5 km map of estimated average number of days per year with at least one 8-hour running mean ozone concentration in excess of 50 ppb (the proposed EPAQS air quality standard for ozone), for the period 1990 to 1994. This map was derived from measurements at RMN sites; the effect of local NO emissions on measured urban ozone concentrations has been estimated using land cover information. The agreement with measurements at AUN and RMN sites is reasonably good (mean of measurements = 16.9 days, mean of estimates at these locations = 18.6 days,  $r = 0.92$ ,  $n = 30$ ). The data acknowledgement for this map is DoE/NETCEN.
- A 1 km x 1 km map of the accumulated exceedance of 40 ppb for daylight hours during the growing period May-July (AOT40 from crops) has been calculated. This map has been provided by ITE at Bush for PORC and was calculated from a combination of measurements at RMN sites and a map of altitude. The influence of urban areas on AOT40 has not been included in this map. The map presented here shows the AOT40 as a percentage of the criterion of 5000 ppb.hours (5 ppm.hours). The data acknowledgement for this map is DoE/ITE.

### 2.4.2 ANNUAL AVERAGE AIR QUALITY CRITERIA EXCEEDANCE MAPS

Table 2 list the maps showing the estimated annual mean air quality as a percentage of relevant air quality criteria that are presented:

TABLE 2 ANNUAL AVERAGE AIR QUALITY CRITERIA EXCEEDANCE MAPS

Pollutant	Annual air quality Criteria ( $\mu\text{gm}^{-3}$ )	Data Acknowledgement
Nitrogen Dioxide	40 WHO Human Health	DoE/NETCEN
Nitrogen Dioxide	30 WHO Ecological Effects	DoE/NETCEN
Lead	0.5 WHO Human Health	DoE/NETCEN
Benzene	16.2 EPAQS proposed AQ standard	DoE/NETCEN
Benzene	3.24 EPAQS proposed AQ target	DoE/NETCEN
1,3-butadiene	2.24 EPAQS proposed AQ standard	DoE/NETCEN
Sulphur Dioxide	50 WHO Human Health	DoE/NETCEN
Sulphur Dioxide	30 WHO Agricultural crops*	DoE/NETCEN/EIC**
Sulphur Dioxide	20 WHO Forests and Natural Veg.*	DoE/NETCEN/EIC**

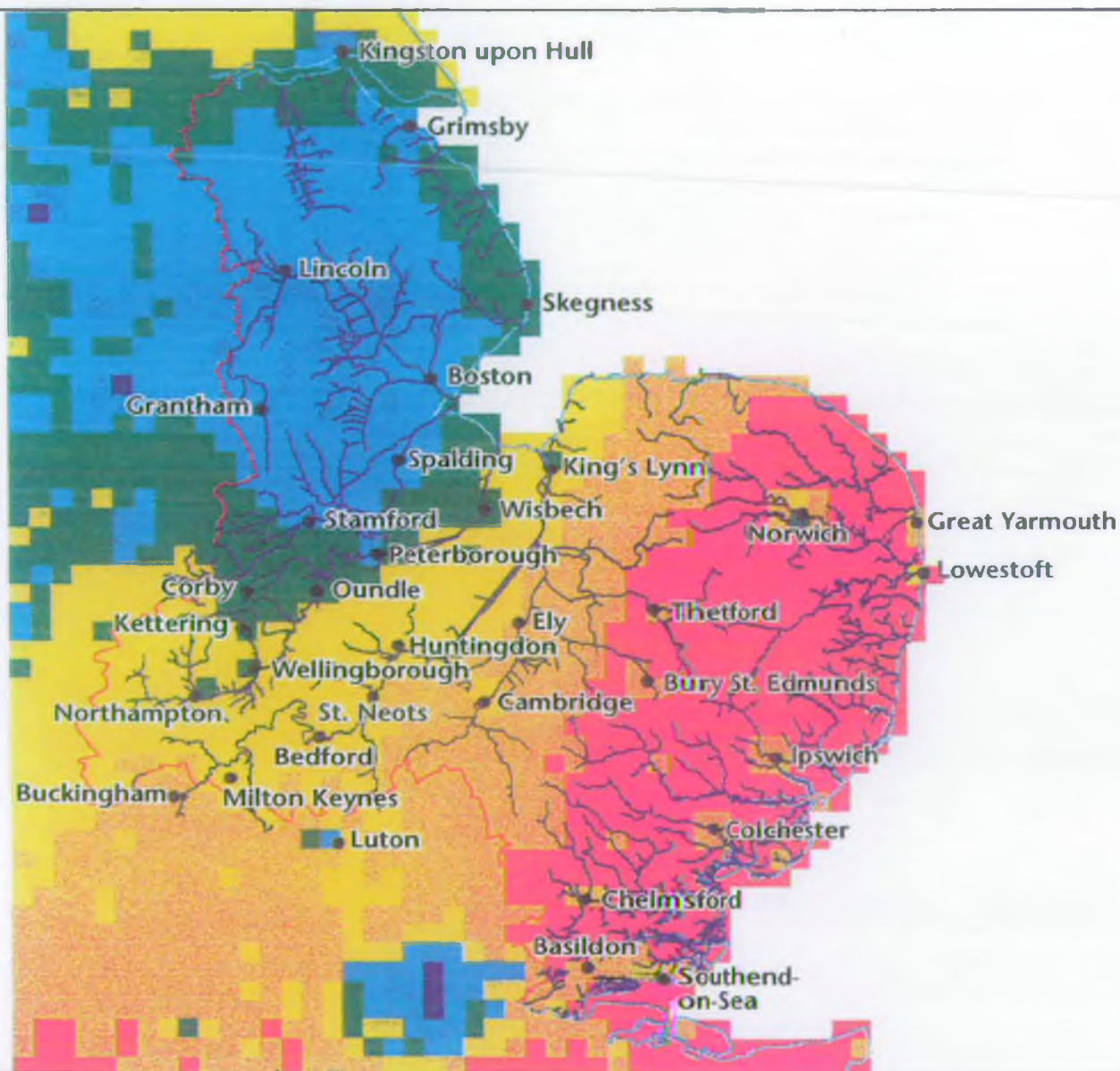
- \* The percentage of the air quality criteria has been calculated with reference to the critical levels map for vegetation for  $\text{SO}_2$ , which is also shown. The critical level for each vegetation type applies to a grid square if at least 5% of the land cover within the square is of the relevant vegetation type. The percentage of the air quality criteria is only shown if at least 5% of the land cover within the square is of the relevant vegetation type. Setting an appropriate critical level for different vegetation types is complicated by the lack of data on the response of different species and varieties at different points in their life cycle and after different prior exposure. For arable crops a critical level of  $30 \mu\text{g SO}_2 / \text{m}^3$  has been adopted and for natural vegetation and forests a critical level of  $20 \mu\text{g SO}_2 / \text{m}^3$ . The distribution of these two land covers has been determined from the ITE Land Cover Map of Great Britain, data has been reclassified from 25 classes to 3 (natural vegetation & forests, arable and other) before aggregating from 25 metre pixels to one kilometre grid cells. Within the Anglian region natural vegetation and forests are dominant in very few grid cells.

\*\*EIC is the Environmental Information Centre at ITE Monks Wood.



# Estimated no of days where Ozone 8hr mean $\geq 50$ ppb, 1990-1994

Ref NETCEN 24/07/96 20008001/JRS UK1KM\_03DAYS1



No. of days



Anglian Region Boundary      Rivers      Coastline

Data Acknowledgement: DoE/NETCEN  
Incorporates monitoring data from: DoE Rural Monitoring Network  
and Automatic Monitoring Network



# Estimated exceedance of AOT40 standard for ozone (5000 ppb.hours) during daylight hours between May-July averaged over 1990-1994



% of standard (5000 ppb.hours)



— Anglian Region Boundary

— Rivers

— Coastline

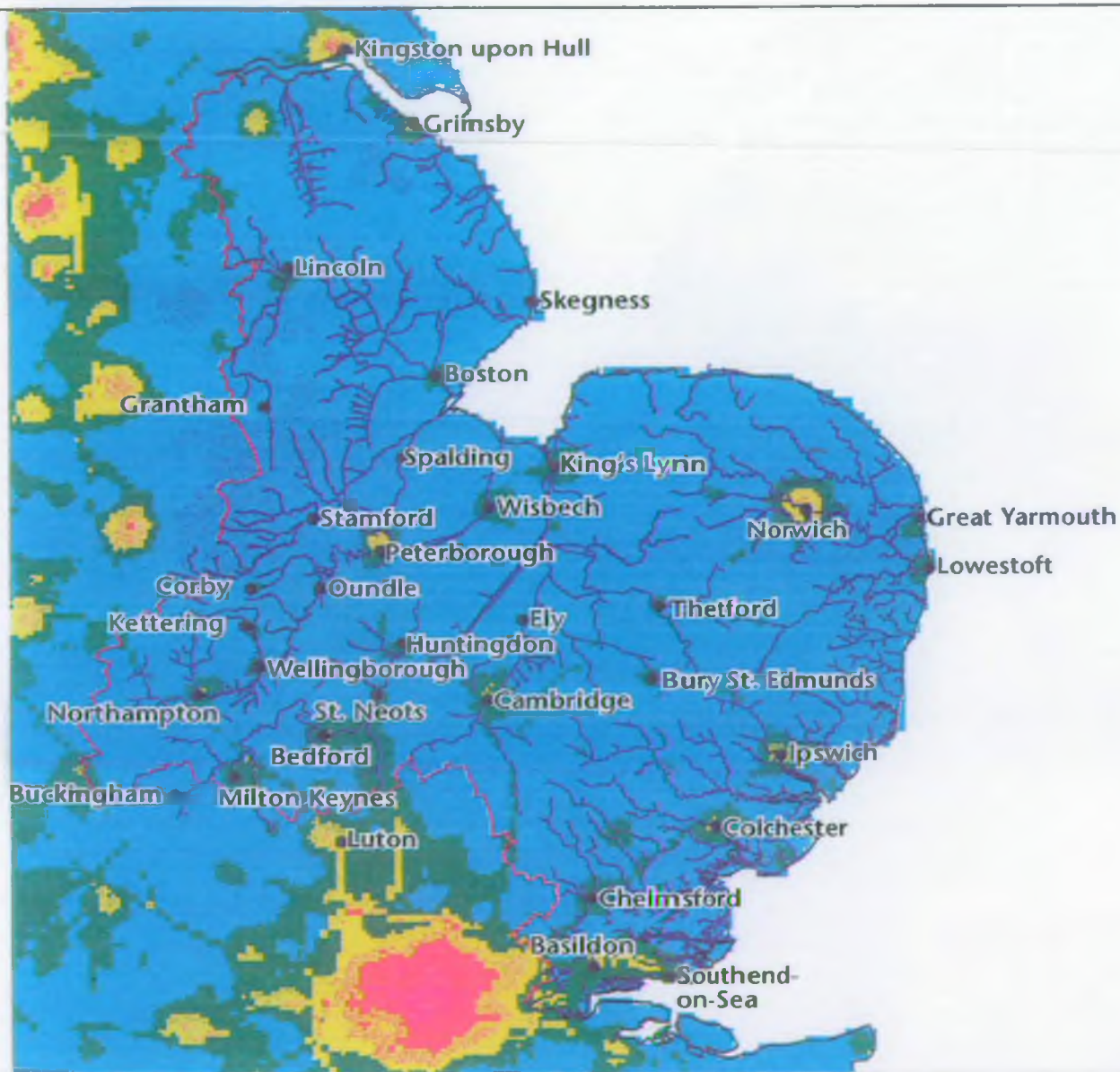
Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Rural Monitoring Network and Automatic Monitoring Network

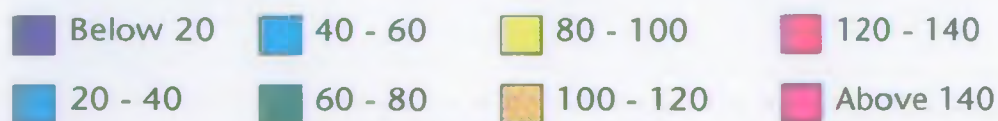


# Estimated percentage of nitrogen dioxide 40 ug/m3 annual mean criterion, 1994

Ref NETCEN 24/07/96 20008001/JRS UK1KM\_NO23



% of standard



— Anglian Region Boundary      — Rivers      — Coastline

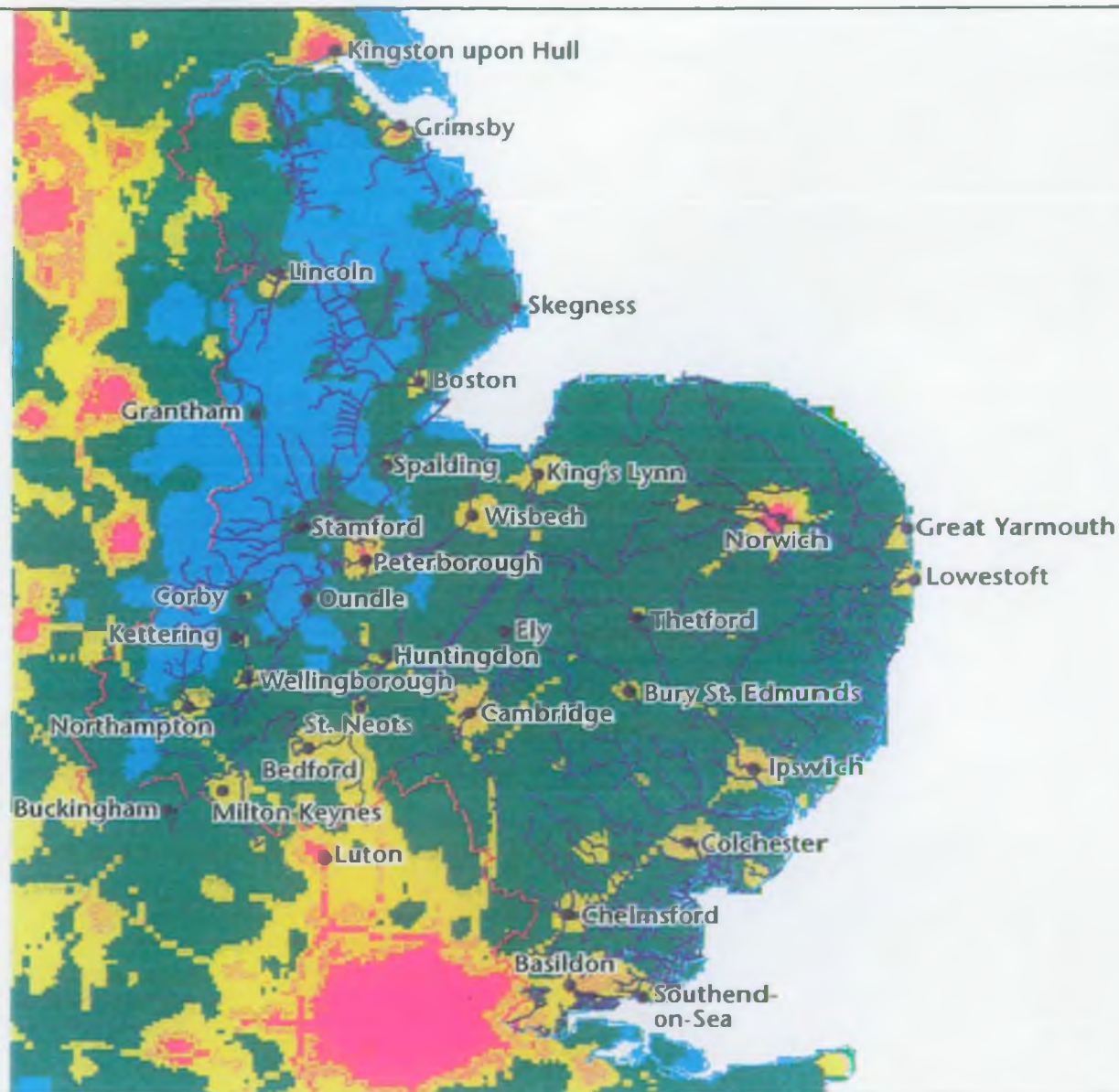
Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Rural Monitoring Network, Automatic Urban Network, Acid Deposition Network and Joint Environment Programme of National Power and PowerGen



# Estimated percentage of nitrogen dioxide 30 ug/m3 annual mean criterion, 1994

Ref NETCEN 24/07/96 20008001/JRS UK1KM\_NO23



% of standard



— Anglian Region Boundary

— Rivers

— Coastline

Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Rural Monitoring Network, Automatic Urban Network, Acid Deposition Network and Joint Environment Programme of National Power and PowerGen

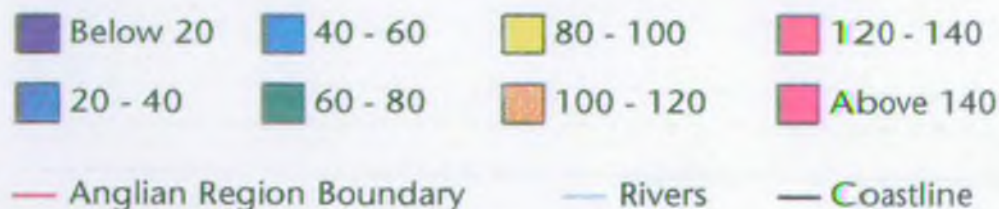


# Estimated percentage of lead 0.5 ug/m3 annual mean criterion, 1994

Ref NETCEN 29/01/97 20008001/JRS UK1KM\_LEAD1



% of standard



Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Lead in Petrol, Multi-element and AEAT Rural Networks



# Estimated percentage of benzene 16.2 ug/m3 annual mean criterion, 1994

Ref NETCEN 15/10/96 20008001/JRS UK1KM\_BZ1



% of standard



— Anglian Region Boundary      — Rivers      — Coastline

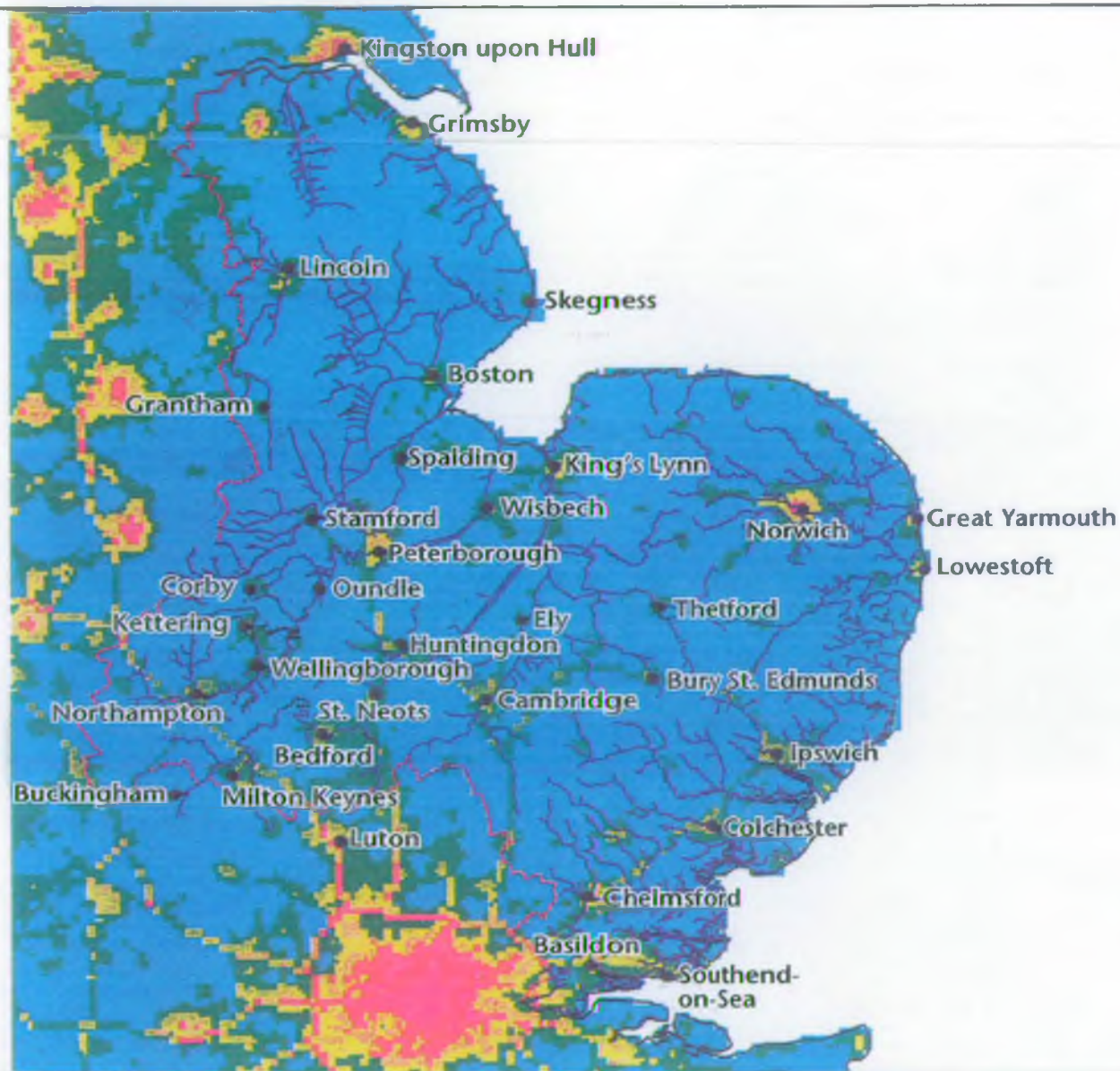
Data Acknowledgement: DoE/NETCEN

Incorporates monitoring data from: DoE Automatic Hydrocarbon Network

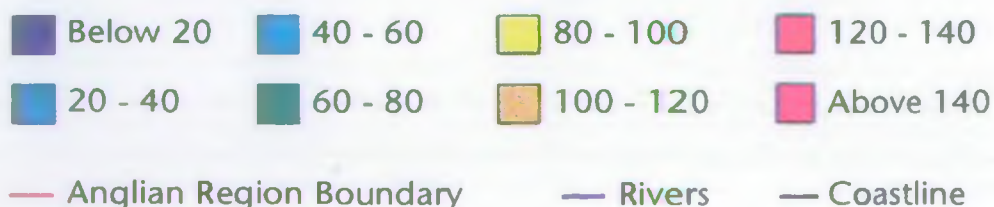


# Estimated percentage of benzene 3.24 ug/m3 annual mean criterion, 1994

Ref NETCEN 15/10/96 20008001/JRS UK1KM\_BZ1



% of standard



Data Acknowledgement: DoE/NETCEN  
Incorporates monitoring data from: DoE Automatic Hydrocarbon Network

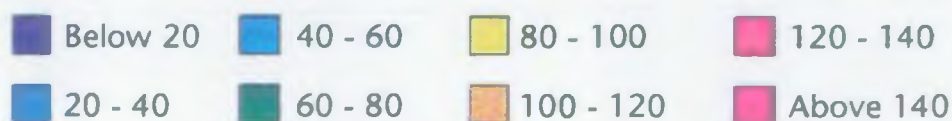


# Estimated percentage of 1,3-butadiene of 2.24 ug/m<sup>3</sup> annual mean criterion, 1994

Ref NETCEN 15/10/96 20008001/JRS UK1KM\_13BUT1



% of standard



— Anglian Region Boundary

— Rivers

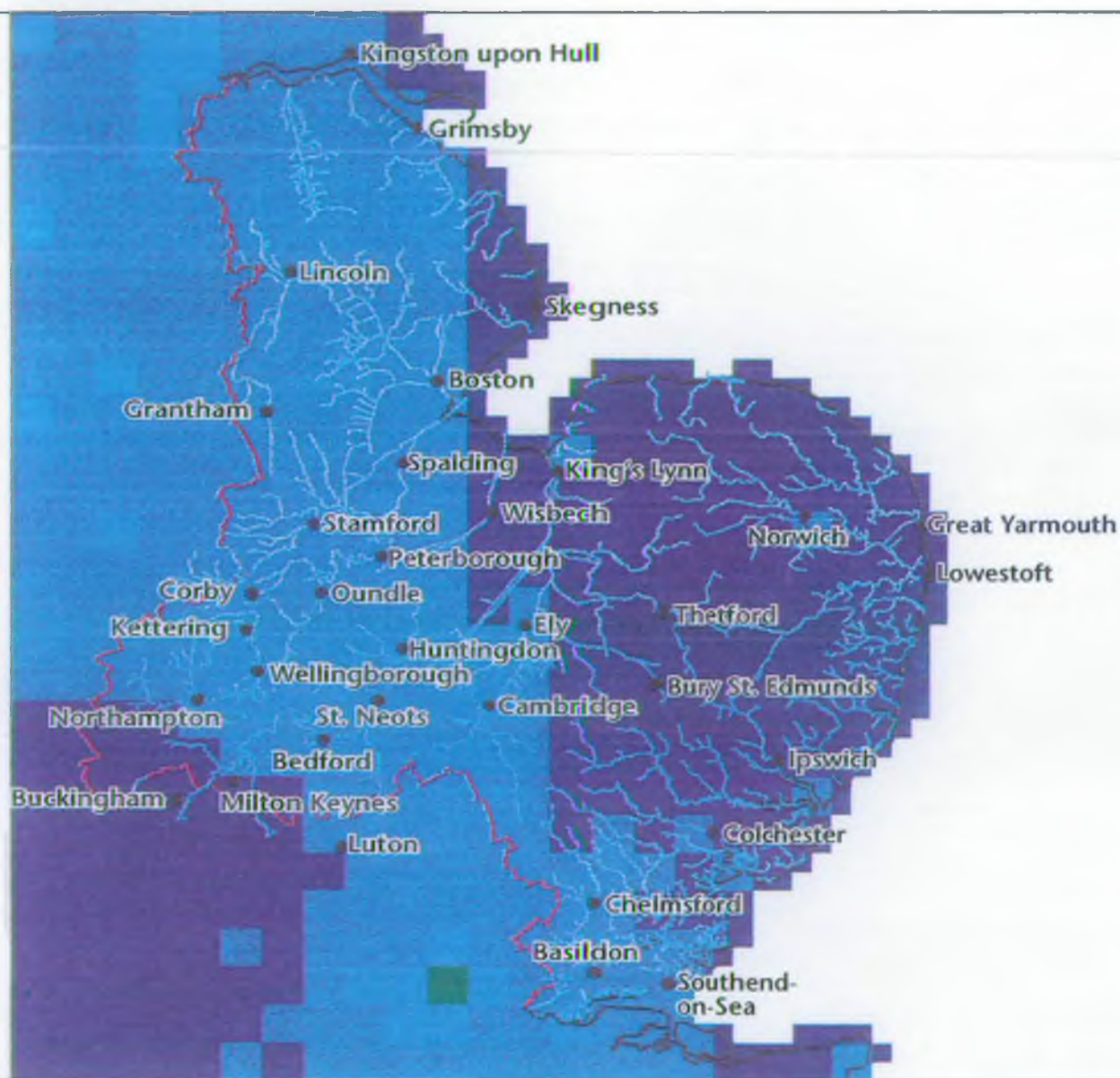
— Coastline

Data Acknowledgement: DoE/ITE/NETCEN

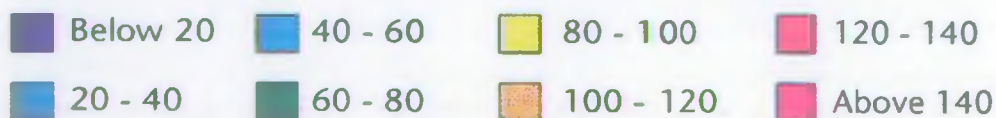
Incorporates monitoring data from: DoE Automatic Hydrocarbon Network

# Estimated percentage of sulphur dioxide 50 ug/m3 annual mean criterion, 1994

Ref NETCEN 21/04/96 20008001/GWC



% of standard



— Anglian Region Boundary

— Rivers

— Coastline

Data Acknowledgement: DoE/NETCEN

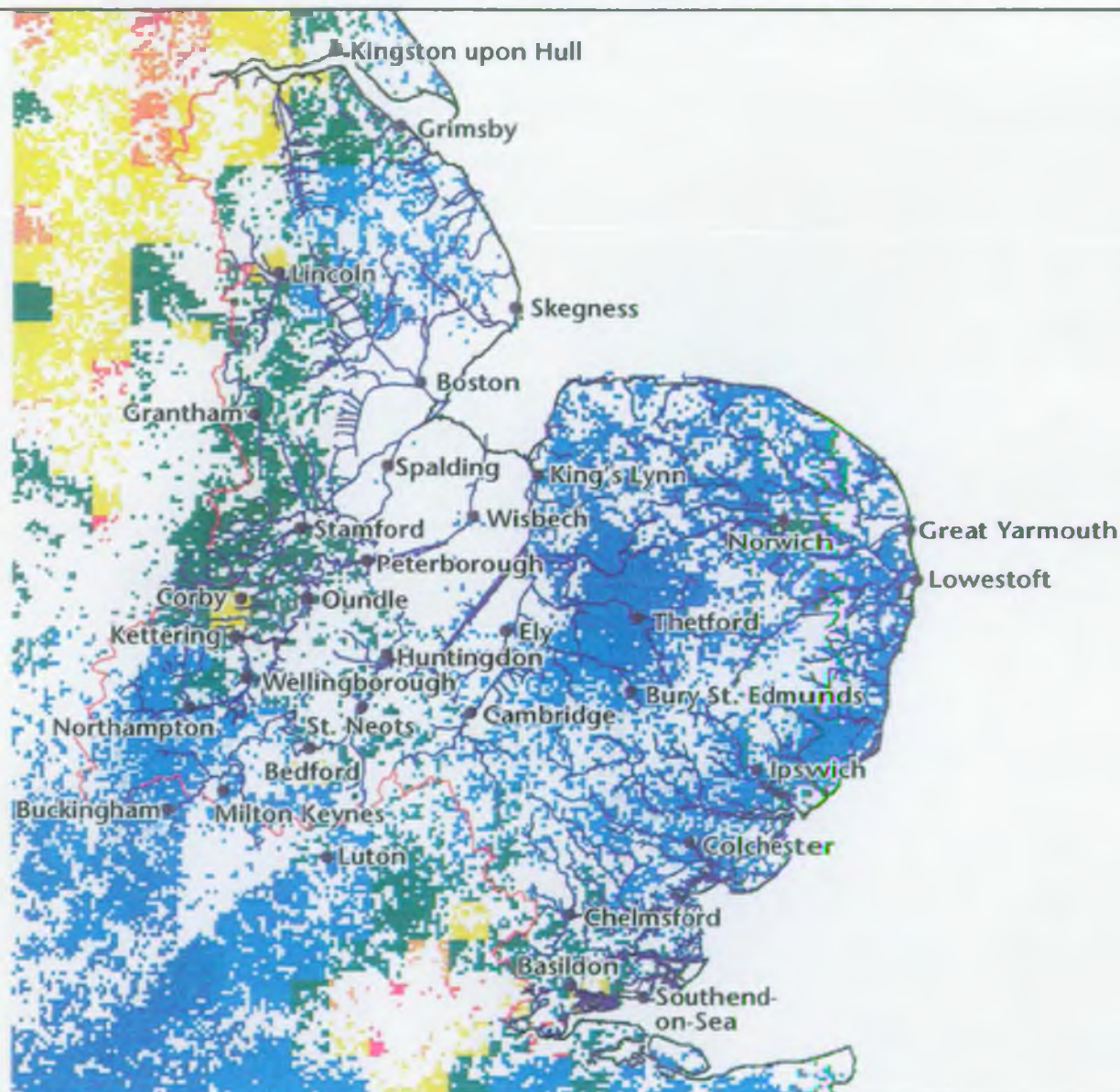
Incorporates monitoring data from: DoE Rural SO<sub>2</sub>, Rural Automatic and Smoke and SO<sub>2</sub> Networks, and Joint Environment Programme of National Power and PowerGen



# Estimated percentage of sulphur dioxide 20 ug/m<sup>3</sup> annual mean criterion, 1994

Ref NETCEN 21/04/96 20008001/GWC

Values shown in forested/natural vegetation areas



% of standard



Data Acknowledgement: DoE/NETCEN/EIC

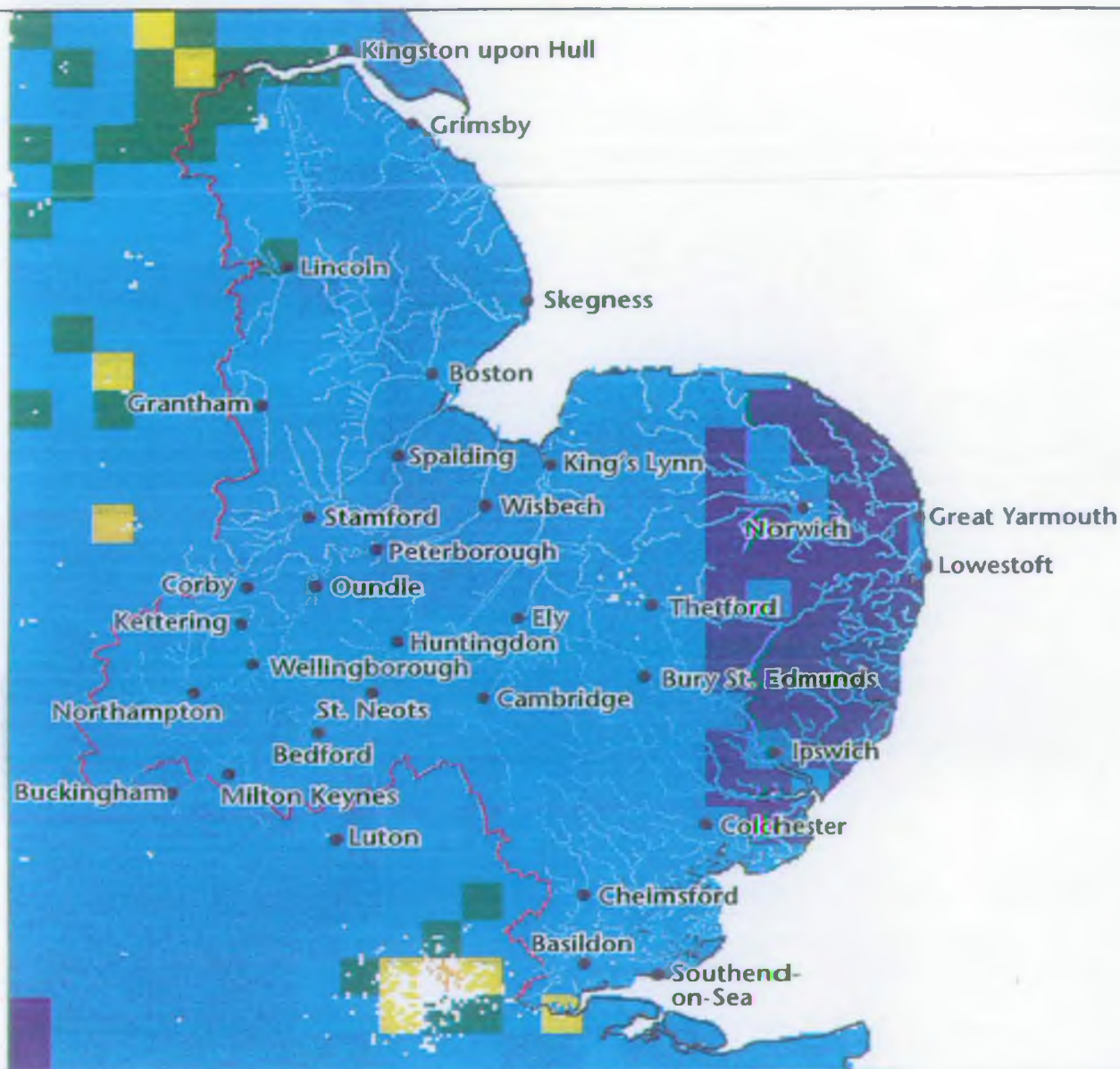
Incorporates monitoring data from: DoE Rural SO<sub>2</sub>, Rural Automatic and Smoke and SO<sub>2</sub> Networks, and Joint Environment Programme of National Power and PowerGen



# Estimated percentage of sulphur dioxide 30 ug/m<sup>3</sup> annual mean criterion, 1994

Ref NETCEN 21/04/96 2000800GWC

Values shown in agricultural areas



% of standard



— Anglian Region Boundary

— Rivers

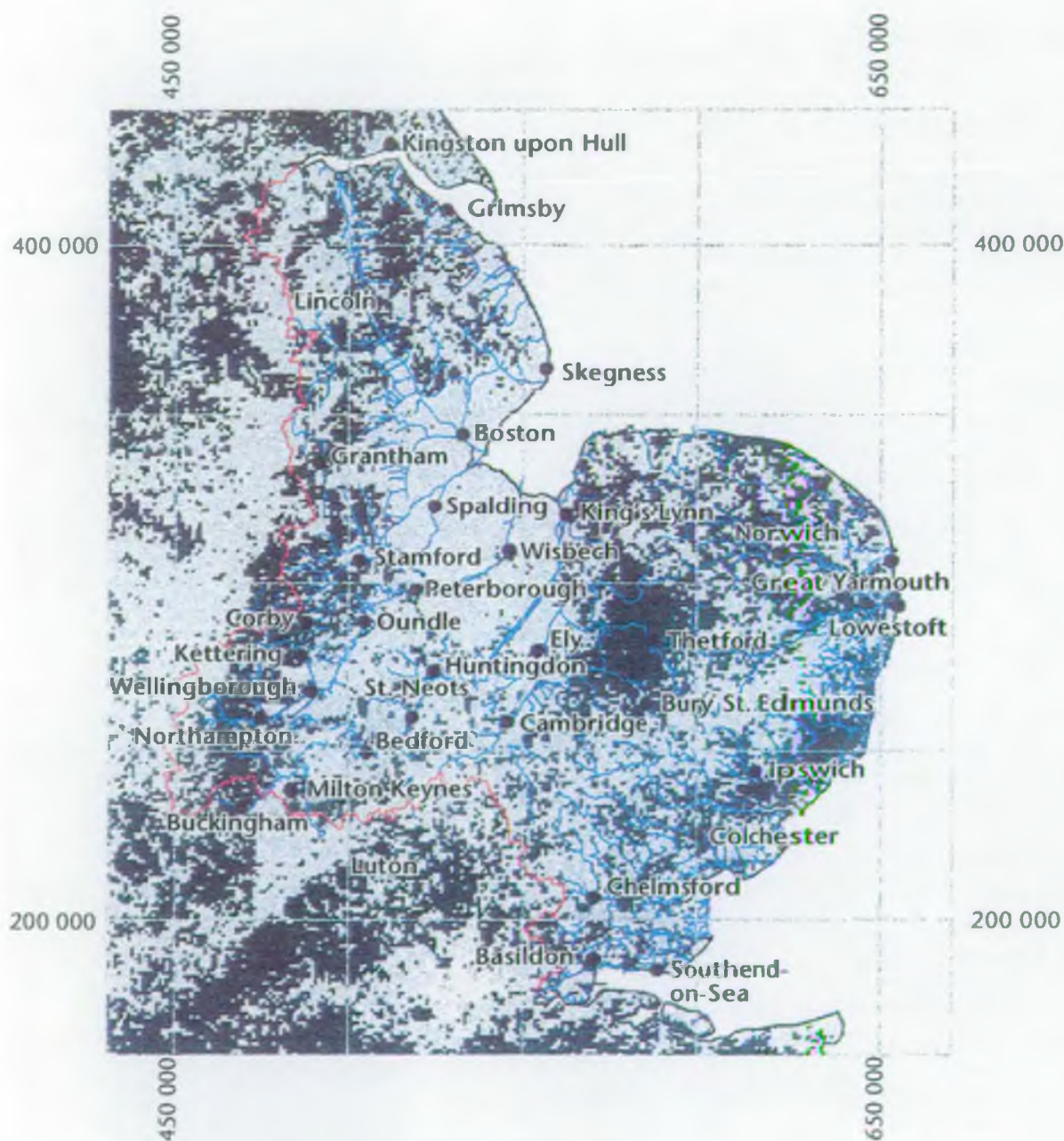
— Coastline

Data Acknowledgement: DoE/NETCEN/EIC

Incorporates monitoring data from: DoE Rural SO<sub>2</sub>, Rural Automatic and Smoke and SO<sub>2</sub> Networks, and Joint Environment Programme of National Power and PowerGen



# 1km Critical Levels of SO<sub>2</sub> for Vegetation for the Anglian Region



Critical Level (ug/m<sup>3</sup>)

■ Forests and Natural Vegetation (20 ug/m<sup>3</sup>)

□ Agricultural Crops (30 ug/m<sup>3</sup>)

□ Other

— Anglian Region Boundary

— Rivers

— Coastline

Critical Loads Mapping and Data Centre, ITE Monks Wood

February 1997

Data acknowledgement: EIC Monks Wood



## 2. 5 SITE SPECIFIC AIR QUALITY MEASUREMENTS

### 2.5.1 AIR QUALITY MEASUREMENTS

All the data reported in this section are based on fully ratified results from Department of the Environment's monitoring networks. These networks are operated to the comprehensive QA/QC procedures developed by NETCEN. The results are for calendar years apart from those from the UK smoke and sulphur dioxide monitoring networks which operate on pollution years (April to March). All concentrations are reported in  $\mu\text{g m}^{-3}$ .

Details of the monitoring stations, measurement methodologies and data analysis are reported on a network-by-network basis :

### 2.5.2 AUTOMATIC MONITORING NETWORKS

These networks provide high temporal resolution measurements of ozone, oxides of nitrogen, carbon monoxide, sulphur dioxide,  $\text{PM}_{10}$  particulate matter and volatile organic compounds. There are currently (January 1997) about 80 such monitoring stations in the UK, over 60 of these being in urban locations.

Each monitoring station utilises instruments which sample and analyse the ambient air continuously. These measurements are stored at site on data logging systems, which are interrogated automatically every hour by modem. Data are then processed by sophisticated computer systems and released as provisional hourly statistics through the DoE's Air Quality Data Dissemination Unit at NETCEN. Provisional results are available on CEEFAX (page 410) and TELETEXT (page 106), a freephone telephone information service (0800 556677) and radio, television and newspaper weather forecasts. Provisional and fully ratified results are available from the UK's air quality archive on the INTERNET (<http://www.aeat.co.uk/netcen/airqual/welcome.html>). The most recently ratified monitoring results for these networks are for 1995.

In the Anglian region there was only one automatic monitoring station operating during 1995, measuring ozone at Sibton in Suffolk. A number of other monitoring sites will be coming on line during 1997, located in Thurrock, Cambridge, Lincoln and Norwich.

The Sibton site is part of the automatic rural monitoring network. The overall objective of this network is to provide information on photochemical pollution across the UK. This information is used to fulfil the requirements of an EC Directive on ozone, as a basis for UK government policy making decisions, for scientific research, and for public information.

Table 3 shows a summary of the monitoring results for 1995, including monthly means, percentile values of hourly data and statistics for comparison with relevant air quality guidelines. The figures show that the EC population information threshold of  $180 \mu\text{g m}^{-3}$  was exceeded 18 times on 6 days at Sibton. The EC population warning value was however not exceeded. The EPAQS recommended guideline for ozone was exceeded 295 times on 35 days, and the objective of  $100 \mu\text{g m}^{-3}$  as the 97%ile of 8-hour running means, as stated in the UK National Air Quality Strategy, was also exceeded ( $104 \mu\text{g m}^{-3}$ ).

Trends in annual mean and maximum hourly concentrations for Sibton ozone are given in Table 4 and shown graphically in Figure 1. It can be seen that there is no obvious trend in ozone concentrations in the Anglian region.

Figure 2 presents diurnal variations in hourly ozone concentrations at Sibton. This clearly shows the high mid-afternoon concentrations which are characteristic of this pollutant during summer episodes.

### 2.5.3 UK SMOKE AND SULPHUR DIOXIDE MONITORING NETWORKS

The UK Smoke and  $\text{SO}_2$  monitoring networks have operated for over 30 years and have successfully monitored the decline in the concentration of these pollutants, resulting both from the successful implementation of the Clean Air Acts and from a nation-wide move towards the use of cleaner fuels.

The following methodologies are used to determine daily average pollutant concentrations:

$\text{SO}_2$       Acid titration method, BS 1747 Part 3 (1991)

Smoke      Reflectance method BS 1747 Part 11 (1993)

The results from all stations are published annually, and the full daily datasets for some sites are supplied to the Commission under the terms of the Exchange of Information Directive. Data summaries are available on the UK's National Air Quality Archive.

There is currently a total of over 220 monitoring sites in these networks, 12 of which are in the Anglian region. The most recently ratified data available are for the pollution year 1995/96, and these are summarised in tables 5 to 8 (Table 9 is a key to the site location codes used in the previous four tables).



The smoke summary statistics show that the only guideline exceeded at these monitoring sites was the  $85 \mu\text{g m}^{-3}$  24 hour mean concentration. Sites in Bedford, Northampton and Norwich breached this threshold.

The  $\text{SO}_2$  summary statistics show that none of the EU directive thresholds were breached in the Anglian region. The health guidelines set by the WHO were also not breached, but one or more of the vegetation guidelines were exceeded at all sites.

Tables 10 to 13 give annual mean and daily maximum Smoke/ $\text{SO}_2$  concentrations for two long-running monitoring sites - Norwich 7 and Southend on Sea 2. Figures 3 to 6 show graphically the long-term decline in both smoke and sulphur dioxide levels at these sites.

#### **2.5.4 RURAL SULPHUR DIOXIDE MONITORING NETWORK**

The objective of this monitoring programme is to map rural  $\text{SO}_2$  concentration across the UK.

At each measurement site, ambient air is drawn through a bubbler containing a dilute hydrogen peroxide solution, similar to that used in the smoke and sulphur dioxide monitoring networks. While daily samples are obtained, these are bulked to provide weekly samples for analysis. Ion chromatography is used to determine sulphate concentrations, thereby avoiding the problem of interference by other gases, notably  $\text{NH}_3$ , which could otherwise reduce the effectiveness of the measurement method in rural areas.

Table 14 gives monitoring data for 1995 and shows concentrations to be well below all guidelines for this pollutant. Table 15 and Figure 7 show how concentrations have declined significantly over the last ten years at the Cardington monitoring station.

#### **2.5.5 RURAL NITROGEN DIOXIDE MONITORING FROM THE UK ACID DEPOSITION MONITORING NETWORKS**

$\text{NO}_2$  diffusion tubes are used to measure monthly mean concentrations at all 32 acid deposition monitoring network sites. Five of these sites are in the Anglian region.

Table 16 gives annual statistics for 1994 which is the most recent set of ratified data. The figures show that the WHO  $40 \mu\text{g m}^{-3}$  guideline was not exceeded at any of these rural monitoring sites.

#### **2.5.6 UK NITROGEN DIOXIDE DIFFUSION TUBE NETWORK**

In 1993, the Department of the Environment funded NETCEN to co-ordinate a large-scale survey of  $\text{NO}_2$  concentrations throughout the UK using passive diffusion tube samplers operated by Local Authorities.

The primary aims of this survey are:

- to identify areas of high  $\text{NO}_2$  concentrations, for further examination;
- to determine the spatial variation of  $\text{NO}_2$  throughout the UK;
- to determine trends in overall UK  $\text{NO}_2$  concentrations over a number of years.

The survey commenced in January 1993 and, at present (August 1996), monitoring is being undertaken at 1190 sites.

Each authority operates 4 diffusion tube monitoring sites: one kerbside, one intermediate and two in urban background locations. Monthly averaged  $\text{NO}_2$  concentrations for all sites are sent by each authority to NETCEN for collation. In addition, DoE funds NETCEN to provide centralised organisation and quality assurance support for the survey.

There are about 30 local authorities in the Anglian region involved in this monitoring survey. Tables 17 to 18 list monthly and annual results for 1994 which is the most recent year of ratified data. It can be seen that the majority of kerbside monitoring sites exceed the WHO  $40 \mu\text{g m}^{-3}$  guideline, and a significant number of intermediate / background sites are also above this threshold.

There are not sufficient years of monitoring data available to calculate any trends in results from this programme.

### Table 3 - Sibton Ozone Statistics for 1995

Units: ug/m3 Network: Automatic Rural Grid Reference: TM364719  
Technique: UV absorption Measurement Frequency: 1 hr

Statistic	ug/m3	
Annual Mean	52	
Hourly Percentiles		
50	52	
84	74	
90	82	
95	94	
98	122	
99	142	
Max. Hour	224	
No. hours $\geq 180 \text{ ug m}^{-3}$	18 on 6 days	EC Population Information.
No. hours $\geq 360 \text{ ug m}^{-3}$	0	EC Population Warning
No. 8-hours $\geq 100 \text{ ug m}^{-3}$	296 on 35 days	EPAQS
97%ile of 8hour mean	104	Exceeds Strategy Objective
Max Running 8 hour	192	

Monthly Mean	ug/m3	Max hr	ug/m3
Jan	42	Jan	78
Feb	48	Feb	84
Mar	56	Mar	92
Apr	64	Apr	108
May	74	May	224
Jun	52	Jun	156
Jul	66	Jul	192
Aug	68	Aug	198
Sep	46	Sep	100
Oct	40	Oct	92
Nov	28	Nov	70
Dec	28	Dec	74

JMax 8hr	ug/m3	Max Day	ug/m3
Jan	72	Jan	64
Feb	78	Feb	68
Mar	84	Mar	76
Apr	102	Apr	90
May	192	May	160
Jun	132	Jun	94
Jul	172	Jul	126
Aug	172	Aug	140
Sep	88	Sep	70
Oct	82	Oct	64
Nov	62	Nov	56
Dec	70	Dec	64

AOT40 for crops, mean of years 1990-94, daylight hours  
May - July (ppb.hours)  
6539

### Table 4 - Sibton O3 Long Term Trends

Units: ug/m3 Network: Automatic Technique: UV absorption.  
Key: \* = not available.

Year	Annual Mean	Max Hrly Av
80	32	126
81	48	414
82	50	248
83	54	266
84	46	248
85	36	176
86	*	*
87	44	200
88	48	212
89	50	244
90	50	290
91	54	180
92	52	246
93	54	244
94	52	254
95	52	224



Table 5 - Smoke Monthly Means and Maximums for Pollution Year 1995/96

Units: ug/m3 Network: Smoke/SO<sub>2</sub> Technique: Filter/Bubbler. Measurement Frequency: 1 day

Site name	Code	Location	Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Jan		Feb		Mar	
			Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
BEDFORD 10	B2	E5056 N2486	4	13	6	20	N	7	N	7	5	13	6	14	11	32	17	91	13	58	11	37	8	26	9	21
IMMINGHAM 6	B2	E5190 N4151	N	N	N	N	N	5	3	8	N	6	N	7	N	N	9	27	14	62	N	50	N	45	N	45
STALLINGBOROUGH 2	O1	E5200 N4133	3	23	N	6	N	5	N	3	N	N	5	13	N	8	18	53	N	N	N	N	N	N	N	N
LOUTH 1	D2	E5332 N3874	7	21	6	17	4	6	5	9	3	7	5	10	11	23	14	31	17	63	14	37	13	30	N	30
THORNTON CURTIS 2	O1	E5121 N4196	3	9	4	8	2	7	4	10	4	12	3	8	8	21	9	25	N	13	N	N	N	N	N	23
GRIMSBY 4	B2	E5245 N4099	4	9	5	16	2	5	3	9	4	6	4	9	6	16	11	47	12	53	12	36	8	23	7	39
LINCOLN 5	A1/E	E4974 N3714	10	41	9	23	5	29	N	9	N	1	N	N	N	20	15	39	13	67	12	33	N	20	N	34
BLETCHLEY 2	B3/E	E4857 N2337	4	9	6	18	6	21	14	27	12	32	3	7	6	15	10	29	N	58	N	27	8	28	13	26
NORTHAMPTON 9	D2/E	E4752 N2610	12	29	14	53	8	15	7	16	11	20	11	26	14	33	23	56	24	125	24	61	18	42	19	39
NORWICH 7	A3	E6233 N3099	5	8	6	20	3	7	4	7	3	8	4	9	7	29	14	67	20	96	12	23	N	45	N	21
SCUNTHORPE 15	D2	E4891 N4113	9	14	8	18	6	9	9	13	8	15	8	22	8	21	14	41	18	67	14	31	N	70	N	N
THURROCK 13	B1	E5622 N1791	6	17	8	29	4	8	5	15	6	17	7	23	12	31	17	58	14	44	14	28	11	35	12	27

Table 6 - Smoke Summary Statistics For Pollution Year 1995/96

Units: ug/m3 Network: Smoke/SO<sub>2</sub> Technique: Filter/Bubbler

EU directive of 34 for annual mean not breached at any site. EU directive of 213 for 98 %ile not breached at any site.

Site	Code	Location	Annual Mean	98th %ile	Max Day	EU 85 Exceeded	Max. day
BEDFORD 10	B2	E5056 N2486	9	39	91	Yes	03/11/95
IMMINGHAM 6	B2	E5190 N4151	10	45	62		11/12/95
STALLINGBOROUGH 2	O1	E5200 N4133	7	39	53		07/11/95
LOUTH 1	D2	E5332 N3874	9	31	63		11/12/95
THORNTON CURTIS 2	O1	E5121 N4196	5	19	25		06/11/95
GRIMSBY 4	B2	E5245 N4099	6	27	53		11/12/95
LINCOLN 5	A1/E	E4974 N3714	11	35	67		08/12/95
BLETCHLEY 2	B3/E	E4857 N2337	9	28	58		09/12/95
NORTHAMPTON 9	D2/E	E4752 N2610	15	42	125	Yes	11/12/95
NORWICH 7	A3	E6233 N3099	8	45	96	Yes	08/12/95
SCUNTHORPE 15	D2	E4891 N4113	12	50	70		01/02/96
STANFORD-LE-HOPE 2	B1	E5692 N1823	7	23	55		31/10/95
THURROCK 13	B1	E5622 N1791	10	31	58		31/10/95

Table 7 - SO<sub>2</sub> Sites Monthly Means and Maximums for Pollution Year 1995/96Units: ug/m<sup>3</sup> Network: Smoke/SO<sub>2</sub> Start of Period: 04/04/95 Technique: Filter/ Acid bubbler. Measurement Frequency: 1 day Key: N= no data available.

Site name	Code	Location	Apr		May		Jun		Jul		Aug		Sep		Oct		Nov		Dec		Jan		Feb		Mar	
			Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max	Mean	Max
BEDFORD 10	B2	E5056 N2486	11	20	11	21	N	35	N	14	12	27	6	20	8	27	8	27	9	33	10	34	10	21	9	20
IMMINGHAM 6	B2	E5190 N4151	N	N	N	N	N	81	27	78	N	36	N	42	N	N	23	67	34	97	N	66	N	57	N	53
STALLINGBOROUGH 2	O1	E5200 N4133	22	42	N	64	N	32	N	34	N	N	10	120	N	N	8	35	N	N	N	N	N	N	N	N
LOUTH 1	D2	E5332 N3874	18	43	18	28	23	55	24	42	28	35	32	48	22	28	22	42	19	35	15	28	20	29	N	29
THORNTON CURTIS 2	O1	E5121 N4196	11	38	15	30	16	80	12	25	12	31	10	19	18	64	16	31	N	40	N	N	N	N	N	76
GRIMSBY 4	B2	E5245 N4099	16	39	16	52	15	39	12	37	12	25	N	N	10	19	9	19	13	32	6	20	14	65	13	26
LINCOLN 5	A1/E	E4974 N3714	23	41	22	42	25	42	N	28	N	14	N	N	N	28	17	27	20	42	21	41	N	34	N	35
BLETCHLEY 2	B3/E	E4857 N2337	12	30	18	36	22	51	30	45	25	51	16	58	17	49	18	31	N	73	N	31	24	74	21	38
NORTHAMPTON 9	D2/E	E4752 N2610	7	13	12	25	14	25	8	19	10	25	N	19	7	38	12	19	14	26	14	27	17	40	15	40
NORWICH 7	A3	E6233 N3099	14	20	23	35	22	33	19	26	19	26	24	35	39	70	39	107	31	90	54	161	N	98	N	18
SCUNTHORPE 15	D2	E4891 N4113	19	44	23	38	12	38	4	13	22	46	13	38	23	38	15	26	18	39	17	52	N	59	N	N
THURROCK 13	B1	E5622 N1791	26	45	32	63	25	50	28	43	29	50	26	58	34	63	34	76	27	90	26	44	33	63	31	64

Table 8 - SO<sub>2</sub> Sites Summary Statistics For Pollution Year 1995/96Units: ug/m<sup>3</sup> Network: Smoke/SO<sub>2</sub> Technique: Acid Bubbler 98%ile of daily means/year EU Directive of 350 not breached at any site.

Site name	Code	Grid	Annual Mean	WHO 30 Exceeded	WHO 20 Exceeded	WHO 10 Exceeded	98th %l	Max day	WHO 100 Exceeded
BEDFORD 10	B2	E5056 N2486	8.83			No	26.92	34.37	
IMMINGHAM 6	B2	E5190 N4151	29.48		Yes	Yes	76.79	95.29	
STALLINGBOROUGH 2	O1	E5200 N4133	19.65			Yes	62.83	117.90	Yes
LOUTH 1	D2	E5332 N3874	21.62		Yes	Yes	41.90	54.02	
THORNTON CURTIS 2	O1	E5121 N4196	14.72			Yes	56.84	78.60	
GRIMSBY 4	B2	E5245 N4099	12.76			Yes	31.92	63.85	
LINCOLN 5	A1/E	E4974 N3714	20.62		Yes	Yes	41.90	41.27	
BLETCHLEY 2	B3/E	E4857 N2337	19.65			Yes	48.86	72.71	
NORTHAMPTON 9	D2/E	E4752 N2610	11.79			Yes	26.92	39.30	
NORWICH 7	A3	E6233 N3099	28.48		Yes	Yes	114.70	158.17	Yes
SCUNTHORPE 15	D2	E4891 N4113	16.69			Yes	43.89	57.95	
STANFORD-LE-HOPE 2	B1	E5692 N1823	32.41	Yes	Yes	Yes	111.72	152.27	Yes
THURROCK 13	B1	E5622 N1791	28.48		Yes	Yes	62.83	88.43	



**Table 9: Smoke/SO<sub>2</sub> Network Site Classification Codes.**

Code	Area Description
A1	Residential area with high-density housing (probably terraced), or with medium-density housing in multiple occupation, in either case surrounded by other built-up areas.
A2	Predominantly A1, but interspersed with some industrial undertakings.
A3	Residential area with high-density housing or medium-density housing in multiple occupation surrounded by, or interspersed with, other areas with low potential air pollution output (parks, fields, coast).
B1	Residential area with medium-density housing, typically an inner suburb or housing estate, surrounded by other built-up areas.
B2	Predominantly B1, but interspersed with some industrial undertakings.
B3	Residential area with medium-density housing surrounded by or interspersed with areas with low potential air pollution output (parks, fields, coast), or any residential area with low-density housing.
C1	Industrial area without domestic premises.
C2	Industrial area interspersed with domestic premises of high density or in multiple occupation.
D1	Commercial area or one with predominantly central heating.
D2	Town centre with limited commercial area, possibly mixed with old residential housing and/or minor industry.
E	Smoke control area or smokeless zone (the letter to be added to the primary classification).
R	Rural community.
O1	Open country but not entirely without source(s) of pollution, eg airfields.
O2	Completely open country; no sources within at least 400 metres.
X	Unclassified site, or mixed area.

**Table 10 - Norwich 7, Long Term Trends in Smoke.**

Location: E6233 N3099 Units: ug/m<sup>3</sup>  
Network: Smoke/SO<sub>2</sub>  
Measurement Frequency: 1 day

Year	Mean	Maximum	EC Mean of 34 Exceeded
62	119	1103	Yes
63	133	1057	Yes
64	128	705	Yes
65	94	458	Yes
66	60	264	Yes
67	25	290	No
68	81	538	Yes
69	39	232	Yes
70	55	313	Yes
71	61	551	Yes
72	51	407	Yes
73	44	383	Yes
74	35	200	Yes
75	30	308	
76	25	359	
77	21	168	
78	23	190	
79	20	176	
80	17	99	
81	20	163	
82	17	180	
83	17	121	
84	17	155	
85	14	83	
86	12	77	
87	12	102	
88	12	71	
89	10	100	
90	12	58	
91	12	92	
92	8	33	
93	8	44	
94	7	76	
95	8	96	

**Table 11 - Southend On Sea 2, Long Term Trends in Smoke.**

Location: E5873 N1862 Units: ug/m3  
Network: Smoke/SO<sub>2</sub> Measurement Frequency: 1 day

Year	Mean	Maximum	EC Mean of 34 Exceeded
62	99	1301	Yes
63	84	809	Yes
64	77	527	Yes
65	68	319	Yes
66	55	371	Yes
67	53	308	Yes
68	49	230	Yes
69	43	260	Yes
70	38	275	Yes
71	34	168	Yes
72	37	204	Yes
73	26	250	
74	24	134	
75	29	129	
76	21	178	
77	23	167	
78	22	70	
79	18	86	
80	14	66	
81	14	67	
82	10	53	
83	11	81	
84	11	74	
85	11	60	
86	11	66	
87	11	67	
88	11	53	
89	9	52	
90	11	55	
91	9	53	
92	8	37	

**Table 12 - Norwich 7, Long Term Trends in SO<sub>2</sub>**

Location: E6233 N3099 Units: ug/m3  
Network: Smoke/SO<sub>2</sub> Measurement Frequency: 1 day

Year	Mean (ug/m3)	Maximum (ug/m3)	WHO Mean Guideline Exceeded
62	89	566	50
63	89	468	50
64	88	340	50
65	75	261	50
66	66	348	50
67	45	253	30
68	49	306	30
69	32	178	30
70	68	268	50
71	65	240	50
72	61	299	50
73	60	265	50
74	52	185	50
75	55	291	50
76	54	234	50
77	50	161	50
78	49	259	30
79	46	119	30
80	39	96	30
81	38	128	30
82	26	72	20
83	28	75	20
84	26	74	20
85	25	95	20
86	27	83	20
87	24	46	20
88	22	53	20
89	18	33	10
90	17	48	10
91	16	47	10
92	18	34	10
93	16	49	10
94	20	57	20
95	29	161	20



**Table 13 - Southend On Sea 2, Long  
Term Trends in SO<sub>2</sub>**

Location: E5873 N1862 Units: ug/m3

Network: Smoke/SO<sub>2</sub> Measurement Frequency: 1 day

Year	Mean (ug/m3)	Maximum (ug/m3)	WHO Mean Exceeded
62	117	1121	50
63	108	669	50
64	108	559	50
65	102	583	50
66	93	452	50
67	92	383	50
68	82	305	50
69	88	344	50
70	84	511	50
71	74	458	50
72	77	249	50
73	77	250	50
74	64	205	50
75	82	323	50
76	75	319	50
77	86	452	50
78	82	284	50
79	74	187	50
80	69	157	50
81	29	69	20
82	18	50	10
83	25	93	20
84	27	167	20
85	36	191	30
86	37	115	30
87	39	81	30
88	39	108	30
89	35	68	30
90	41	102	30
91	29	83	20
92	29	66	20

Table 14 - Rural SO<sub>2</sub> Sites Mean Monthly Data for 1995Units: ug/m<sup>3</sup> Network: Rural Sulphur Dioxide. Technique: Bubbler with ion chromatographic analysis.

Site Name	Frequency	Map Reference	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Caenby 1	Weekly	SK 993900	3.82	5.11	7.67	4.69	3.49	3.77	5.05	2.84	3.85	2.71	2.53	1.75
Cardington 2	Weekly	TL 082464	6.45	7.81	9.84	7.24	4.67	4.68	3.43	2.65	4.41	3.76	6.42	5.15
Husbourne Crawley 1	Weekly	SP 964361	3.96	3.08	4.58	4.97	4.89	5.86	4.67	5.06	2.84	1.9	13.69	4.23
Stoke Ferry	Daily	TL 700988	8.46	5.48	8.72	8.80	7.31	4.98	3.88	4.01	4.69	2.93	5.53	6.21

Table 15 - Rural SO<sub>2</sub> Long Term Trends of Annual Mean DataUnits: ug/m<sup>3</sup> Network: Rural Sulphur Dioxide. Technique: Bubbler with ion chromatographic analysis. Key: N= no data available.

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Measurement Frequency	
												Daily from	Weekly from
Husborne Crawley 1	34.6	21.2	17.8	14.4	12.8	8.9	7.9	6.0	5.2	N	8.1	Apr-66	Aug-91
Cardington	52.9	36.9	36.4	26.7	20.7	20.2	18.3	18.6	13.6	7.9	10.7	Mar-82	Aug-91
Caenby 1	23.6	20.2	16.8	12.6	11.8	10.5	11.8	15.5	15.5	N	7.9	Apr-63	Aug-91
Stoke Ferry	12.6	11.3	11.8	8.9	8.9	N	8.4	7.6	6.3	N	5.8	Aug-81	Still daily

Table 16 - Rural NO<sub>2</sub> Monthly and Annual Data for 1994Units: ug/m<sup>3</sup> Network: Acid Deposition. Technique: Diffusion tube. Measurement Frequency: Monthly WHO annual mean guideline of 40 not breached at any site.

Site	Grid	Annual Mean	Monthly Max	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Driby	TF 386744	16.98	27.4	24.6	19.2	17.3	12.2	6.8	10.0	10.5	12.0	16.0	22.0	27.4	26.3
Flatford Mill	TM 077333	21.43	35.7	35.7	30.8	26.5	17.9	13.2	13.0	15.0	12.8	19.2	26.7	24.3	24.8
Jenny Hurn	SK 816986	22.97	36.7	29.9	34.0	22.7	14.7	14.9	14.7	16.0	15.8	20.5	26.5	36.7	32.1
Stoke Ferry	TL 700988	20.87	33.1	27.8	22.9	15.8	15.4	12.4	13.3	13.7	14.3	19.4	27.6	31.0	33.1
Woburn	SP 964361	27.09	43.1	24.6	43.1	18.4	22.4	22.2	15.4	25.2	23.5	30.8	36.5	37.2	29.5

Long term trends in NO<sub>2</sub> at Stoke Ferry Units: ug/m<sup>3</sup> Network: Acid Deposition. Technique: Diffusion tube.

1987: 25. 1988: 26. 1989: 27. 1990: 22. 1991: 24. 1992: 24. 1993: 20. 1994: 21



Table 17: NO<sub>2</sub> Sites (Kerbside) Monthly Mean Data For 1994

Units: ug/m3 Network: NO<sub>2</sub> Diffusion Tube Measurement Frequency: Monthly Key:N= no data available.

	Grid E	Grid N	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Mean	WHO 40 Breach
BRIGG 1N	5002	4071	51.13	40.4	41.4	32.5	38.4	44.4	31.6	44.4	40.4	46.2	40.4	51.1	51.1	41.9	Yes
CORBY 1N	4881	2885	34.78	55.5	28.8	30.6	53.6	N	45.1	52.5	40.6	49.3	51.9	36.8	55.5	43.6	Yes
LOUTH 5N	5332	3873	42.3	60.0	43.2	45.3	52.1	49.3	N	48.3	51.1	60.0	62.0	43.2	62.0	50.6	Yes
BOSTON 1N	5330	3439	38.54	35.0	28.8	26.3	32.1	25.4	28.6	22.9	37.0	28.6	38.4	21.2	38.5	30.3	
GRAYS 1N	5615	1781	64.29	71.6	53.4	57.0	59.6	56.6	80.3	57.3	53.6	69.2	62.6	65.6	80.3	62.6	Yes
BEDFORD 5N	5051	2497	37.22	34.4	37.2	N	44.7	45.9	49.4	43.4	48.7	38.9	35.9	39.7	49.4	41.4	Yes
CROMER 1N	6217	3422	45.68	50.2	43.6	45.5	35.5	39.1	40.2	36.3	41.9	47.8	46.1	51.5	51.5	43.6	Yes
RUSHDEN 1N	4958	2666	61.1	N	60.0	56.4	57.9	51.3	70.3	30.1	56.6	N	78.6	62.8	78.6	58.5	Yes
LINCOLN 3N	4978	3713	69.93	38.4	70.9	58.1	69.9	83.7	73.9	67.9	74.8	63.0	66.0	75.8	83.7	67.7	Yes
BRAINTREE 1N	5756	2229	40.60	38.2	N	21.6	39.3	35.7	51.1	36.1	44.6	43.6	49.1	37.2	51.1	39.7	Yes
BROADLAND 1N	6217	3116	28.95	54.7	45.3	31.8	49.8	31.2	52.5	28.4	52.5	41.7	50.0	44.7	54.7	42.7	Yes
CAMBRIDGE 1N	5454	2584	73.50	85.9	71.8	82.0	N	69.7	92.9	63.2	77.1	80.8	84.2	84.2	92.9	78.6	Yes
SPALDING 2N	5356	3255	32.52	13.7	19.7	24.6	29.5	19.7	22.6	28.6	34.4	35.3	34.4	40.4	40.4	28.0	
STAMFORD 1N	5029	3070	45.30	46.4	N	44.9	N	42.5	51.7	44.9	39.3	40.8	42.5	40.8	51.7	44.0	Yes
CHELMSFORD 1N	5714	2059	38.72	N	30.5	34.4	38.0	37.4	41.4	30.1	48.9	41.4	58.3	35.7	58.3	39.5	Yes
COLCHESTER 5N	5999	2246	66.92	72.8	61.1	50.2	67.9	67.9	76.7	75.8	73.9	76.7	65.0	52.1	76.7	67.3	Yes
GRANTHAM 11N	4914	3357	64.10	86.7	44.2	N	81.0	62.0	90.1	66.4	79.0	66.0	70.7	64.9	90.1	70.5	Yes
FELIXSTOWE 1N	6302	2352	59.78	55.6	52.8	44.4	43.6	42.3	45.5	38.9	41.9	54.3	59.4	69.4	69.4	50.6	Yes
BIGGLESWADE 1N	5190	2445	37.22	43.4	N	41.9	36.7	32.7	47.4	N	37.6	40.2	42.9	36.5	47.4	39.7	Yes
NORTHAMPTON 1N	4752	2607	40.60	40.6	36.8	32.5	42.3	37.4	22.6	31.2	42.5	35.2	56.8	39.5	56.8	38.2	
GAINSBOROUGH 1N	4817	3901	51.51	46.8	39.9	39.3	38.2	31.4	28.0	38.5	48.1	55.6	41.0	N	55.6	41.7	Yes
GREAT GRIMSBY 1N	5265	4086	49.25	50.8	54.5	51.7	40.0	51.9	45.9	38.2	35.5	N	55.1	56.4	56.4	48.1	Yes
PETERBOROUGH 1N	5193	2982	N	N	N	48.1	N	42.1	N	N	48.9	48.3	46.1	N	48.9	N	
MILTON KEYNES 1N	4853	2391	73.32	69.0	37.4	41.5	48.1	56.0	56.0	42.3	42.7	52.8	50.8	39.1	73.3	50.8	Yes
NORTH HYKENHAM 1N	4938	3665	54.52	33.8	18.8	30.1	N	28.2	45.1	39.5	N	45.1	35.7	32.0	54.5	36.3	
SAFFRON WALDEN 1N	5537	2384	64.86	66.7	54.3	61.1	46.1	43.8	63.4	52.8	62.6	56.2	57.9	65.4	66.7	57.9	Yes
WELLINGBOROUGH 1N	4893	2677	58.65	52.1	56.8	54.3	59.6	55.3	54.7	48.3	58.5	56.2	49.1	54.3	59.6	54.9	Yes
BURY ST EDMUNDS 1N	5852	2655	62.41	67.9	52.3	56.0	59.0	43.8	56.4	54.5	54.5	63.0	56.0	59.6	67.9	57.2	Yes

Table 18 - NO<sub>2</sub> Sites (Intermediate/Background) Monthly Mean Data For 1994 (Part 1)Units: ug/m<sup>3</sup>. Network: NO<sub>2</sub> Diffusion Tube. Measurement Frequency: Monthly. Key: I= intermediate B= background N= no data available

	Type	Grid E	Grid N	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Mean	WHO 40
BOSTON 2N	I	5330	3439	39.4	31.0	32.5	26.1	23.9	24.6	21.6	20.5	25.8	27.4	28.0	32.0	39.5	27.8	
BOSTON 3N	B	5331	3439	N	28.8	29.1	19.2	16.5	19.4	20.1	19.7	30.6	34.0	43.6	21.2	43.6	25.8	
BOSTON 4N	B	5341	3427	28.8	26.1	19.9	11.7	10.9	N	11.5	13.0	19.0	24.1	27.6	13.2	28.8	18.6	
BRIGG 2N	I	5002	4071	33.5	40.4	34.4	22.6	34.4	31.6	22.6	32.5	32.5	N	34.4	38.4	40.4	32.5	
BRIGG 3N	B	5002	4070	26.5	32.5	27.6	19.7	21.6	26.5	16.7	21.6	24.6	27.6	27.6	31.6	32.5	25.4	
CORBY 2N	I	4880	2887	28.6	38.7	22.4	22.2	34.6	22.4	24.4	27.6	27.4	35.2	35.5	31.4	38.7	29.1	
CORBY 3N	B	4881	2890	30.6	31.8	22.9	22.4	26.5	21.4	19.4	31.0	26.1	31.4	41.0	34.0	41.0	28.2	
CORBY 4N	B	4884	2881	34.2	56.8	26.7	25.6	46.6	26.9	29.1	35.2	35.7	37.2	44.9	37.8	56.8	36.5	
GRAYS 2N	I	5616	1782	72.9	66.6	56.6	35.0	57.2	59.8	59.8	43.4	62.8	65.2	52.1	60.9	72.9	57.7	Yes
GRAYS 3N	B	5618	1799	49.8	53.4	42.1	34.2	32.7	28.0	36.5	25.9	40.8	45.1	44.4	49.6	53.4	40.2	Yes
GRAYS 4N	B	5608	1784	43.1	47.2	37.8	30.3	31.0	21.4	36.5	30.5	37.4	42.7	40.0	40.6	47.2	36.5	
LOUTH 2N	I	5332	3873	49.3	42.3	32.5	30.5	21.6	27.6	15.8	31.6	28.6	42.3	49.3	45.3	49.3	34.8	
LOUTH 3N	B	5334	3875	40.4	28.6	36.5	26.5	16.7	20.7	16.7	24.6	22.6	41.4	47.2	37.4	47.2	29.9	
LOUTH 4N	B	5333	3872	32.5	36.5	13.7	26.5	19.7	N	N	23.7	N	N	N	37.4	37.4	27.1	
BEDFORD 6N	I	5062	2502	33.3	28.2	36.3	22.2	29.5	22.9	29.9	24.3	36.1	36.1	27.6	33.8	36.3	30.1	
BEDFORD 7N	B	5072	2514	30.5	27.1	21.4	17.1	18.6	16.2	18.2	14.7	21.6	25.9	N	29.3	30.5	21.8	
CROMER 2N	I	6219	3420	30.1	31.2	28.2	24.8	20.3	22.6	21.8	23.9	25.2	33.7	37.4	34.2	37.4	27.8	
CROMER 6N	B	6227	3412	26.7	33.5	20.5	18.2	10.0	14.9	14.9	12.8	16.0	26.1	37.0	34.0	37.0	22.0	
LINCOLN 1N	B	4960	3688	38.4	30.5	32.5	23.7	20.7	26.5	21.6	22.6	24.6	34.4	33.5	37.4	38.4	28.8	
LINCOLN 2N	I	4973	3703	52.1	31.6	48.3	39.3	39.3	43.2	41.4	41.4	44.4	41.4	41.4	53.2	53.2	43.1	Yes
LINCOLN 4N	B	4973	3715	43.2	32.5	34.4	29.5	32.5	30.5	30.5	31.6	33.5	40.4	43.2	45.3	45.3	35.5	
RUSHDEN 2N	I	4958	2665	36.3	N	33.5	28.4	24.3	26.3	26.3	25.8	32.9	34.8	49.6	33.1	49.6	32.0	
RUSHDEN 3N	B	4964	2663	44.4	N	33.7	24.4	12.6	20.1	20.1	15.0	31.4	35.5	47.9	40.8	47.9	29.7	
RUSHDEN 4N	B	4949	2655	32.3	N	24.3	22.6	20.1	18.0	22.0	19.9	N	N	N	39.5	39.5	24.8	
BRAINTREE 2N	I	5757	2229	30.3	28.6	N	20.3	25.0	26.9	29.5	25.2	32.7	30.8	36.7	39.9	39.9	29.7	
BRAINTREE 3N	B	5771	2231	27.6	28.6	12.4	15.4	16.9	20.7	25.8	22.4	27.4	30.8	37.0	34.4	37.0	25.0	
BRAINTREE 4N	B	5758	2234	14.5	32.0	N	17.3	18.2	20.7	25.0	22.0	26.5	36.7	36.8	22.7	36.8	24.8	
BROADLAND 2N	I	6252	3085	16.9	29.7	26.5	19.2	18.6	23.9	23.1	16.5	23.7	24.8	31.2	24.8	31.2	23.3	
BROADLAND 3N	B	6242	3127	26.1	26.9	23.5	19.2	15.6	13.2	16.5	15.8	18.0	25.2	29.3	29.7	29.7	21.6	
BROADLAND 4N	B	6267	3086	26.3	26.9	23.3	15.8	12.8	14.1	15.0	13.2	17.9	25.2	24.3	24.8	26.9	19.9	
SPALDING 3N	I	5355	3254	29.5	38.4	16.7	19.7	20.7	11.8	N	N	24.6	30.5	26.5	31.6	38.4	25.0	
SPALDING 5N	B	5365	3251	38.4	34.4	23.7	18.6	19.7	13.7	19.7	39.3	N	N	42.3	42.3	42.3	29.1	
SPALDING 6N	B	5244	3105	N	18.6	N	N	19.7	14.9	24.6	N	24.6	36.5	N	43.2	43.2	25.9	
STANSTED 4N	B	5513	2254	39.9	37.8	23.9	23.1	20.3	19.9	23.7	20.3	26.9	35.7	34.4	40.8	40.8	29.0	
CAMBRIDGE 2N	I	5462	2589	60.9	63.5	59.2	51.7	30.6	35.7	54.1	37.8	42.9	53.8	67.9	63.2	67.9	51.7	Yes
CAMBRIDGE 3N	B	5466	2577	40.0	51.3	38.0	34.2	32.1	26.5	31.2	28.6	37.2	44.4	46.8	48.9	51.3	38.4	
CAMBRIDGE 4N	B	5459	2601	50.6	60.3	44.2	40.6	36.8	29.7	37.2	27.6	N	49.8	53.6	56.6	60.3	44.4	Yes
GRANTHAM 12N	I	4915	3357	56.0	58.3	40.0	66.6	35.7	48.1	48.7	45.5	45.7	53.0	52.8	55.8	66.6	50.6	Yes
GRANTHAM 13N	B	4928	3370	42.5	46.4	23.1	22.4	16.7	25.8	15.0	20.7	30.3	35.7	39.9	38.0	46.4	29.7	
GRANTHAM 14N	B	4899	3357	46.8	49.3	22.7	25.4	19.6	27.3	21.2	21.2	27.3	37.2	43.6	46.8	49.3	32.3	
HAVERHILL 4N	B	5674	2458	42.1	51.5	28.0	28.0	16.7	22.0	21.4	N	30.8	N	47.2	N	51.5	32.0	
STAMFORD 12N	I	5029	3072	45.5	44.6	33.8	34.2	32.7	33.1	35.7	37.8	40.2	40.0	41.7	47.2	47.2	38.9	

Table 18 - NO<sub>2</sub> Sites (Intermediate/Background) Monthly Mean Data For 1994 (Part 2)

Units: ug/m3. Network: NO<sub>2</sub> Diffusion Tube. Measurement Frequency: Monthly. Key: I= intermediate B= background N= no data available

	Type	Grid E	Grid N	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Max	Mean	WHO 40
STAMFORD 24N	B	5010	3077	49.3	38.4	40.0	28.8	20.1	36.7	28.6	27.8	30.5	40.0	49.6	52.8	52.8	36.8	
STAMFORD 13N	B	5026	3077	47.9	41.0	30.3	23.3	17.9	24.8	21.2	23.9	27.1	39.7	36.7	49.4	49.4	32.0	
CHELMSFORD 2N	I	5713	2057	34.2	N	33.1	28.0	21.8	22.0	20.7	24.4	41.4	41.4	54.5	35.7	54.5	32.5	
CHELMSFORD 3N	B	5709	2058	30.8	N	20.1	24.3	20.5	20.1	22.4	22.6	37.6	33.8	41.4	28.2	41.4	27.4	
CHELMSFORD 5N	B	5707	2050	35.3	N	20.1	22.4	18.0	N	19.6	22.6	26.3	22.6	37.6	32.0	37.6	25.6	
COLCHESTER 6N	I	5999	2246	56.0	53.2	51.1	43.2	67.9	42.3	43.2	40.4	37.4	43.2	42.3	33.5	67.9	46.2	Yes
COLCHESTER 7N	B	6003	2256	52.1	58.1	39.3	17.7	48.3	28.6	31.6	21.6	N	36.5	N	N	58.1	37.0	
COLCHESTER 8N	B	5971	2242	47.2	49.3	41.4	20.7	45.3	25.6	23.7	22.6	25.6	31.6	18.6	28.6	49.3	31.6	
FELIXSTOWE 2N	I	6302	2353	50.2	46.6	43.6	34.0	26.1	30.3	34.2	27.1	37.0	49.4	50.0	49.8	50.2	39.9	Yes
FELIXSTOWE 3N	B	6299	2494	46.4	41.0	37.6	25.6	30.8	25.2	25.0	19.4	26.1	34.4	37.8	42.5	46.4	32.7	
FELIXSTOWE 4N	B	6305	2347	43.4	40.8	37.8	28.8	19.2	21.2	23.7	20.1	24.6	41.2	41.7	41.4	43.4	32.0	
BIGGLESWADE 2N	I	5194	2446	30.5	23.7	16.4	24.8	19.2	23.9	25.2	28.2	28.4	33.5	91.0	35.5	91.0	31.8	
BIGGLESWADE 3N	B	5188	2443	28.8	33.8	18.4	24.8	28.2	21.6	22.6	20.9	28.8	29.7	20.3	29.1	33.8	25.6	
BIGGLESWADE 4N	B	5195	2444	24.2	33.8	N	18.0	16.2	21.1	N	20.3	28.8	26.9	32.7	26.1	33.8	24.8	
NORTHAMPTON 2N	I	4752	2610	29.9	59.6	25.0	23.1	35.0	23.9	48.1	21.4	38.9	22.0	40.2	N	59.6	33.5	
NORTHAMPTON 3N	B	4815	2639	32.5	64.1	25.6	26.9	13.7	N	N	N	N	19.6	53.0	28.0	64.1	32.9	
NORTHAMPTON 5N	B	4756	2606	28.6	47.2	21.6	17.5	23.5	14.9	26.1	25.8	22.2	18.6	63.4	27.3	63.4	28.0	
GAINSBOROUGH 2N	I	4813	3899	45.5	41.4	35.5	34.0	24.6	28.0	45.1	25.0	34.4	47.8	52.3	69.9	69.9	40.2	Yes
GAINSBOROUGH 3N	B	4824	3906	33.5	29.9	24.6	17.5	12.2	16.0	18.4	16.2	21.4	31.8	37.2	40.6	40.6	25.0	
GAINSBOROUGH 4N	B	4815	3904	33.8	31.2	24.1	21.2	13.3	15.4	18.6	15.8	25.4	32.1	40.0	38.7	40.0	25.8	
KILLINGHOLME 4N	B	5146	4173	41.4	49.3	38.4	34.4	26.5	37.4	29.5	25.6	24.6	62.0	51.1	50.2	62.0	39.3	
PETERBOROUGH 2N	I	5193	2983	N	N	N	N	N	N	N	N	43.1	N	47.4	45.7	47.4	N	
PETERBOROUGH 3N	B	5161	2991	N	N	N	30.8	27.4	21.6	N	20.1	35.9	40.4	41.2	43.1	43.1	32.5	
PETERBOROUGH 4N	B	5188	2959	N	N	N	32.0	25.2	21.1	N	N	38.0	41.9	N	46.2	46.2	34.0	
GREAT GRIMSBY 2N	I	5265	4086	58.3	116.7	53.6	59.0	62.8	49.6	53.6	43.2	52.5	N	61.7	60.0	116.7	60.9	Yes
GREAT GRIMSBY 3N	B	5282	4098	43.1	37.6	38.5	26.5	16.2	23.3	21.1	22.7	N	N	45.3	42.1	45.3	31.6	
GREAT GRIMSBY 4N	B	5252	4091	34.4	37.2	25.8	23.7	15.4	24.1	25.8	22.6	28.8	N	39.3	34.4	39.3	28.4	
ILTON KEYNES 2N	I	4853	2392	51.3	66.7	24.1	36.1	39.3	41.0	41.0	29.7	39.3	49.3	40.4	37.4	66.7	41.4	Yes
MILTON KEYNES 3N	B	4852	2392	41.5	60.3	23.5	28.8	34.2	38.9	38.9	32.5	35.0	49.1	50.4	50.8	60.3	40.2	Yes
MILTON KEYNES 4N	B	4814	2388	36.1	52.6	19.4	20.5	30.5	27.6	27.6	25.2	31.4	36.3	43.1	30.1	52.6	31.8	
NORTH WALSHAM 7N	B	6283	3309	32.3	41.5	26.3	24.6	12.4	15.6	10.5	15.4	N	40.0	38.9	43.2	43.2	27.4	
NORTH HYKENHAM 3N	B	4948	3665	28.2	22.6	11.3	15.0	13.2	16.9	18.8	16.9	24.4	28.2	24.4	24.4	28.2	20.3	
NORTH HYKENHAM 4N	B	4940	3668	33.8	16.9	11.3	15.0	13.2	16.9	15.0	N	18.8	45.1	18.8	24.4	45.1	20.9	
NORTH HYKENHAM 5N	I	4942	3668	32.0	28.2	15.0	26.3	22.6	22.6	32.0	22.6	28.2	37.6	32.0	26.3	37.6	27.1	
SAFFRON WALDEN 2N	I	5537	2384	39.5	51.5	24.4	32.5	38.2	26.5	39.7	27.6	37.4	42.1	38.9	43.4	51.5	36.8	
SAFFRON WALDEN 3N	B	5536	2382	39.5	40.2	24.4	23.9	22.7	18.2	20.5	21.2	31.4	35.7	32.9	39.9	40.2	29.	
WELLINGBOROUGH 2N	I	4894	2676	38.2	36.8	26.3	27.1	27.4	23.9	29.5	22.2	31.0	40.8	41.7	42.3	42.3	32.3	
WELLINGBOROUGH 3N	B	4885	2678	34.8	39.9	26.7	22.9	N	20.1	21.6	18.4	26.7	32.5	36.3	34.0	39.9	28.6	
WELLINGBOROUGH 4N	B	4898	2683	34.8	38.2	30.3	27.1	30.5	26.3	29.3	21.6	24.1	37.6	38.5	40.6	40.6	31.6	
BURY ST EDMUNDS 2N	I	5851	2657	32.9	59.0	32.1	36.5	39.9	28.0	42.1	30.5	25.8	46.6	47.9	40.6	59.0	38.5	
BURY ST EDMUNDS 5N	B	5838	2634	33.7	41.5	N	19.2	N	15.0	14.9	15.8	17.5	36.3	27.3	36.1	41.5	25.8	



Figure 1 - Sibton O3 Long Term Trends

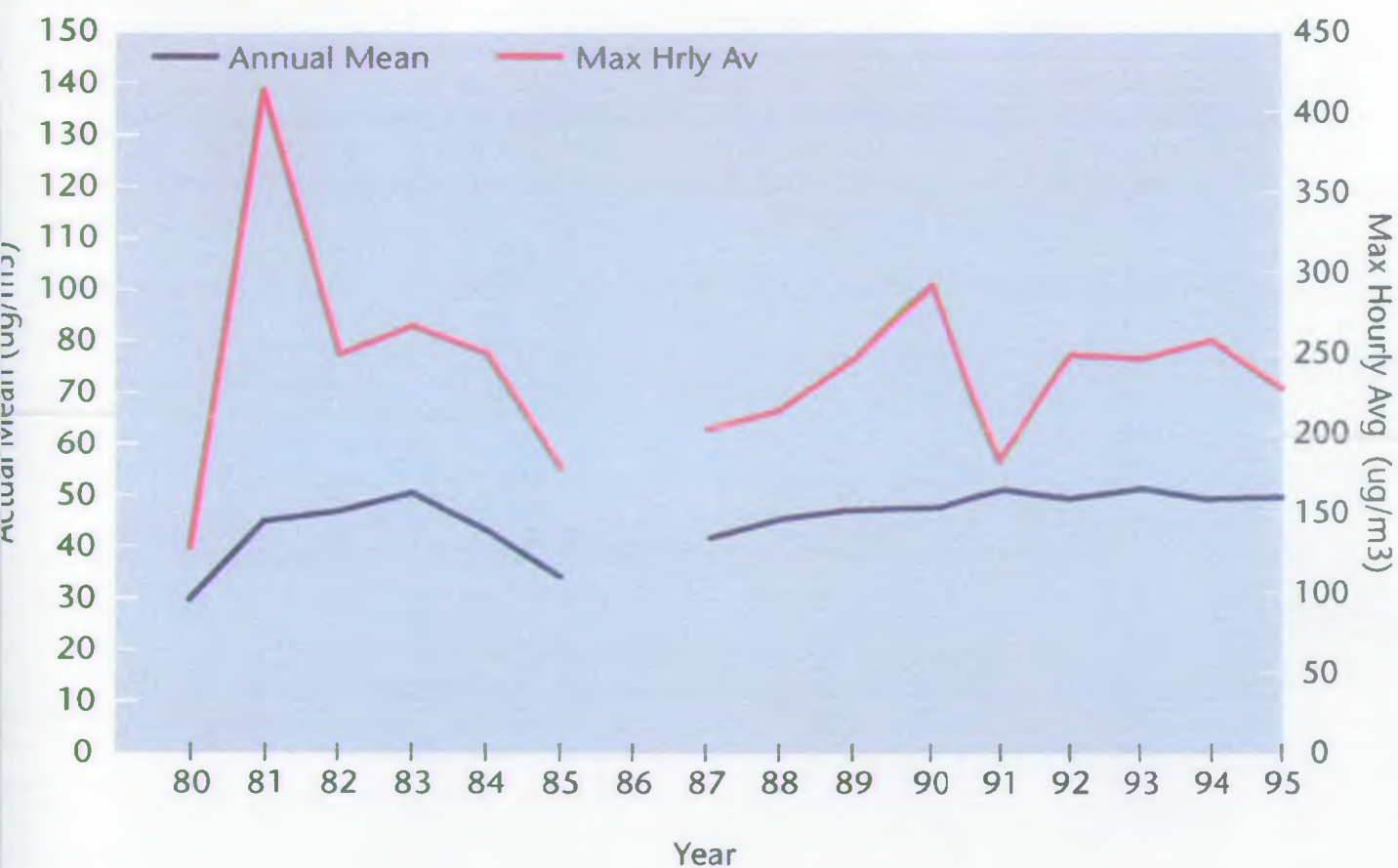


Figure 2 - Sibton O3 Seasonal Diurnal Variation for 1995

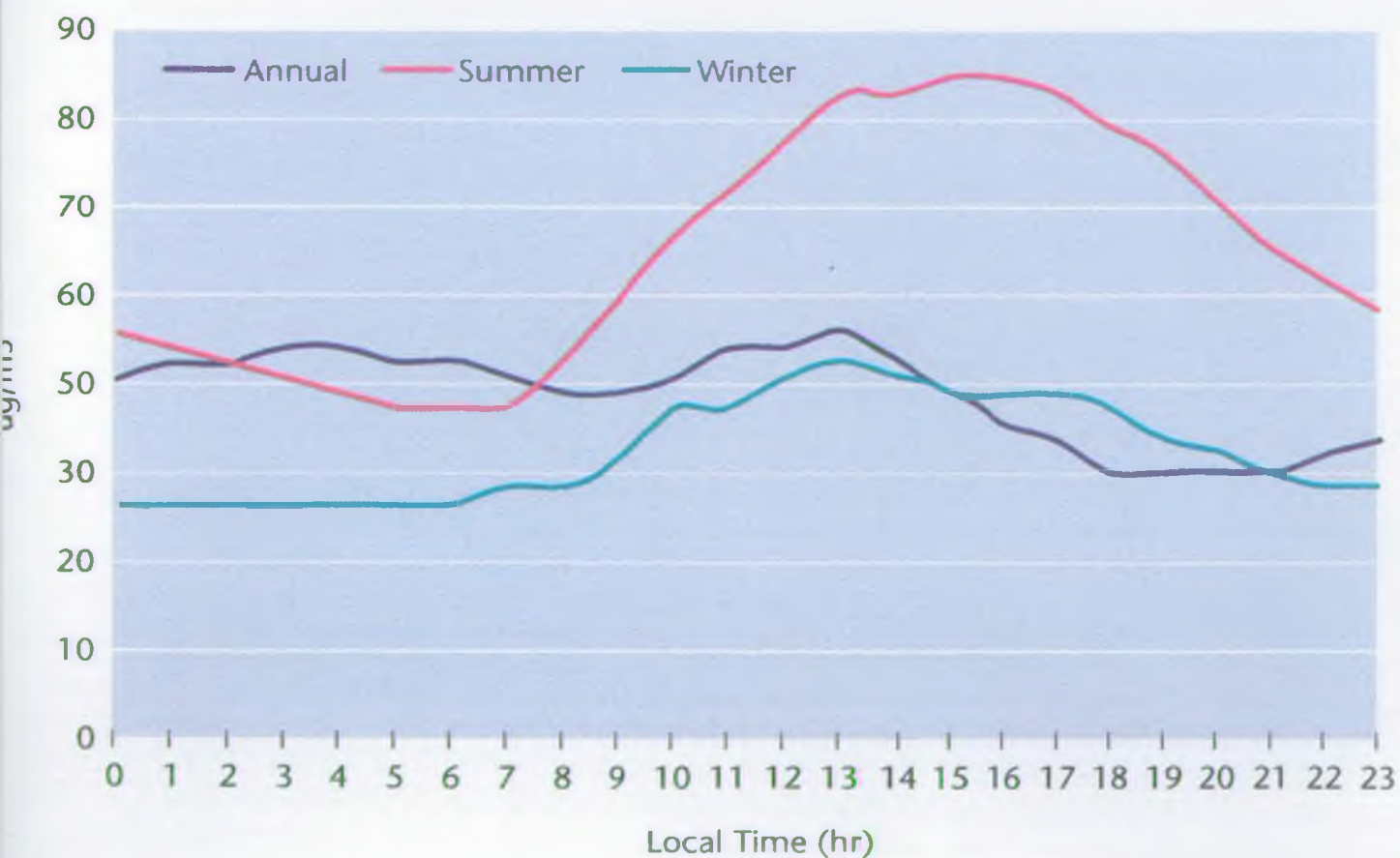


Figure 3 - Norwich 7, Smoke Long Term Trends in Annual Mean and Maximum

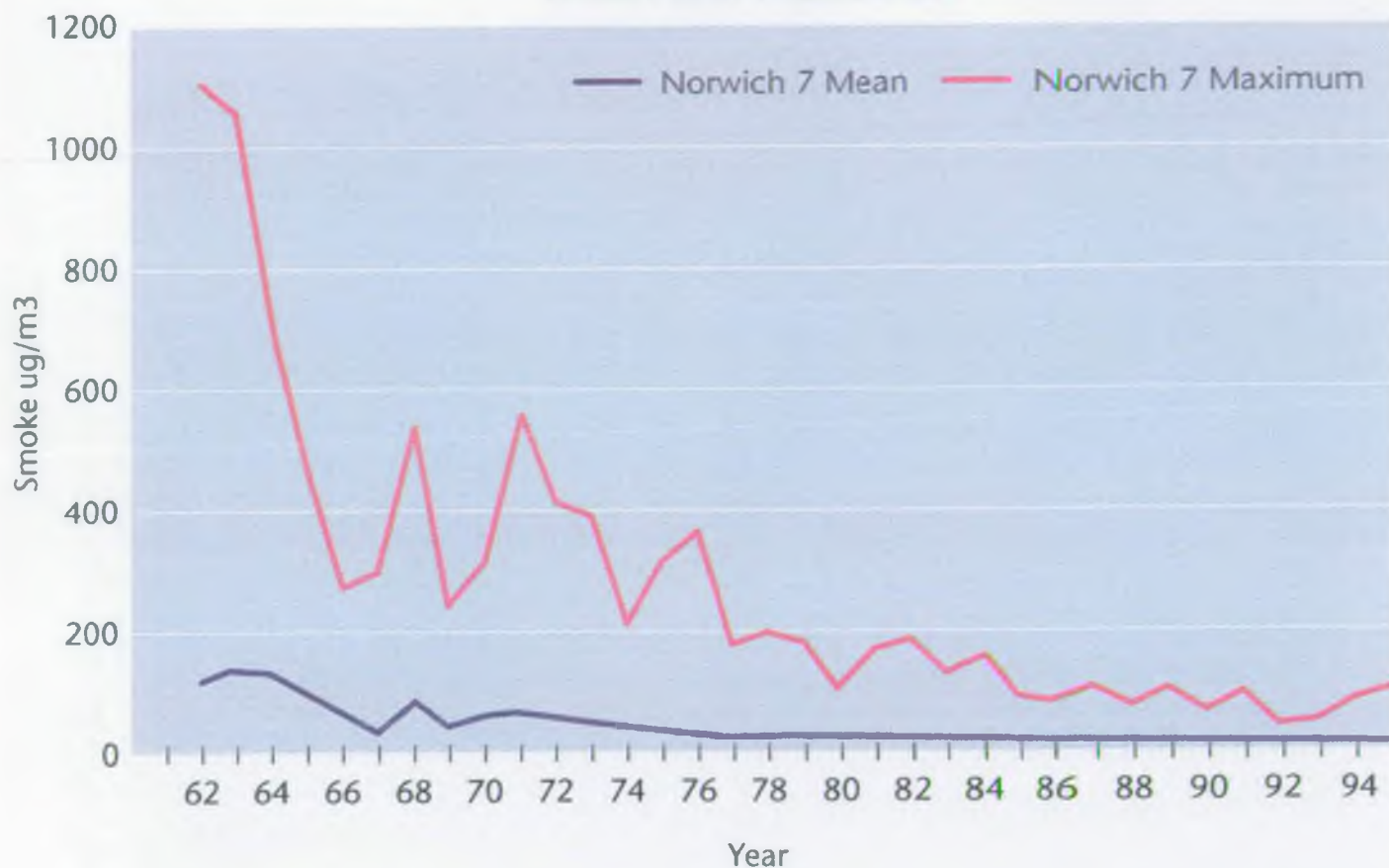


Figure 4 - Southend On Sea 2, Smoke Long Term Trends in Annual Mean and Maximum

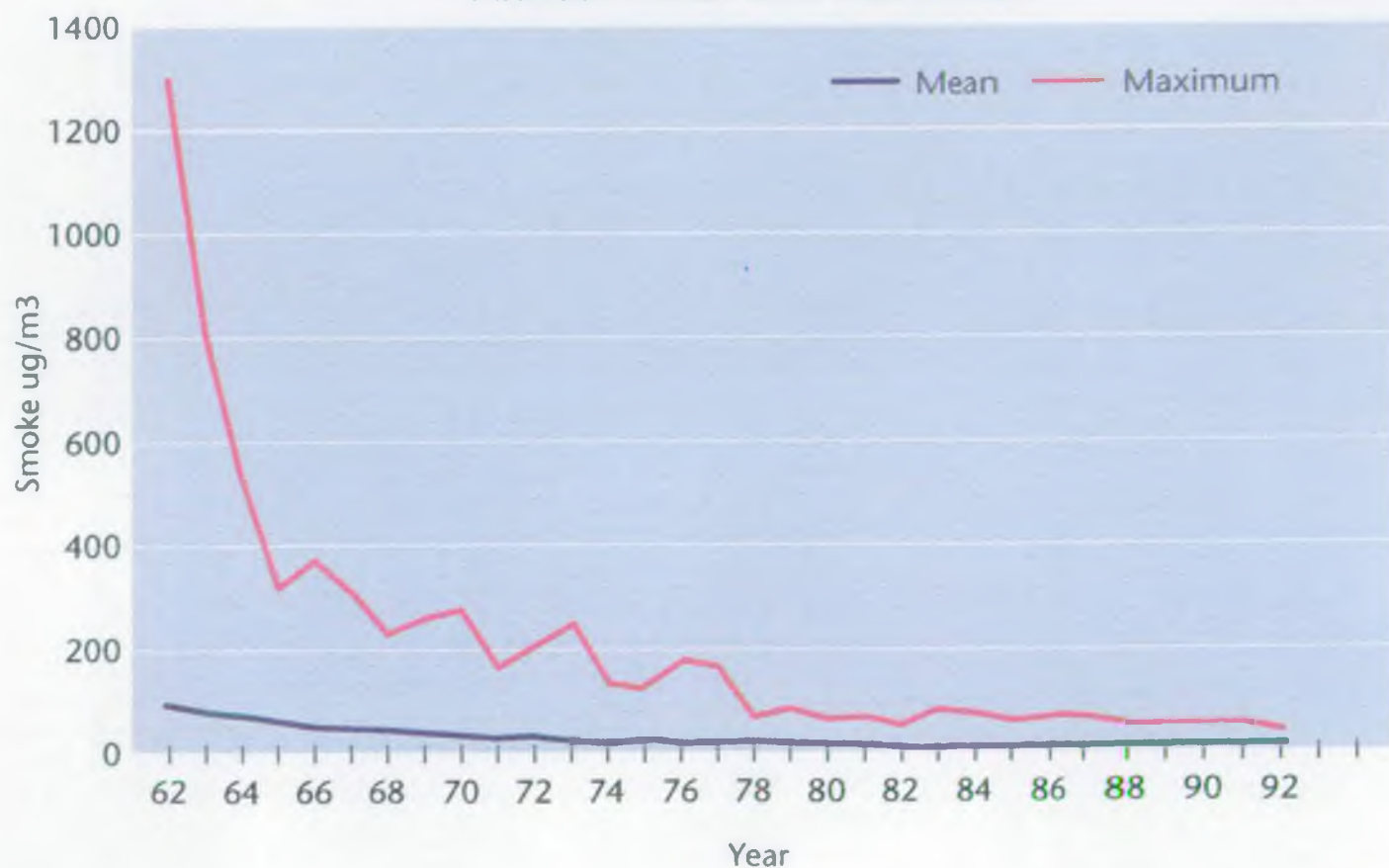




Figure 5 - Norwich 7, SO<sub>2</sub> Long Term Trends in Annual Mean and Maximum

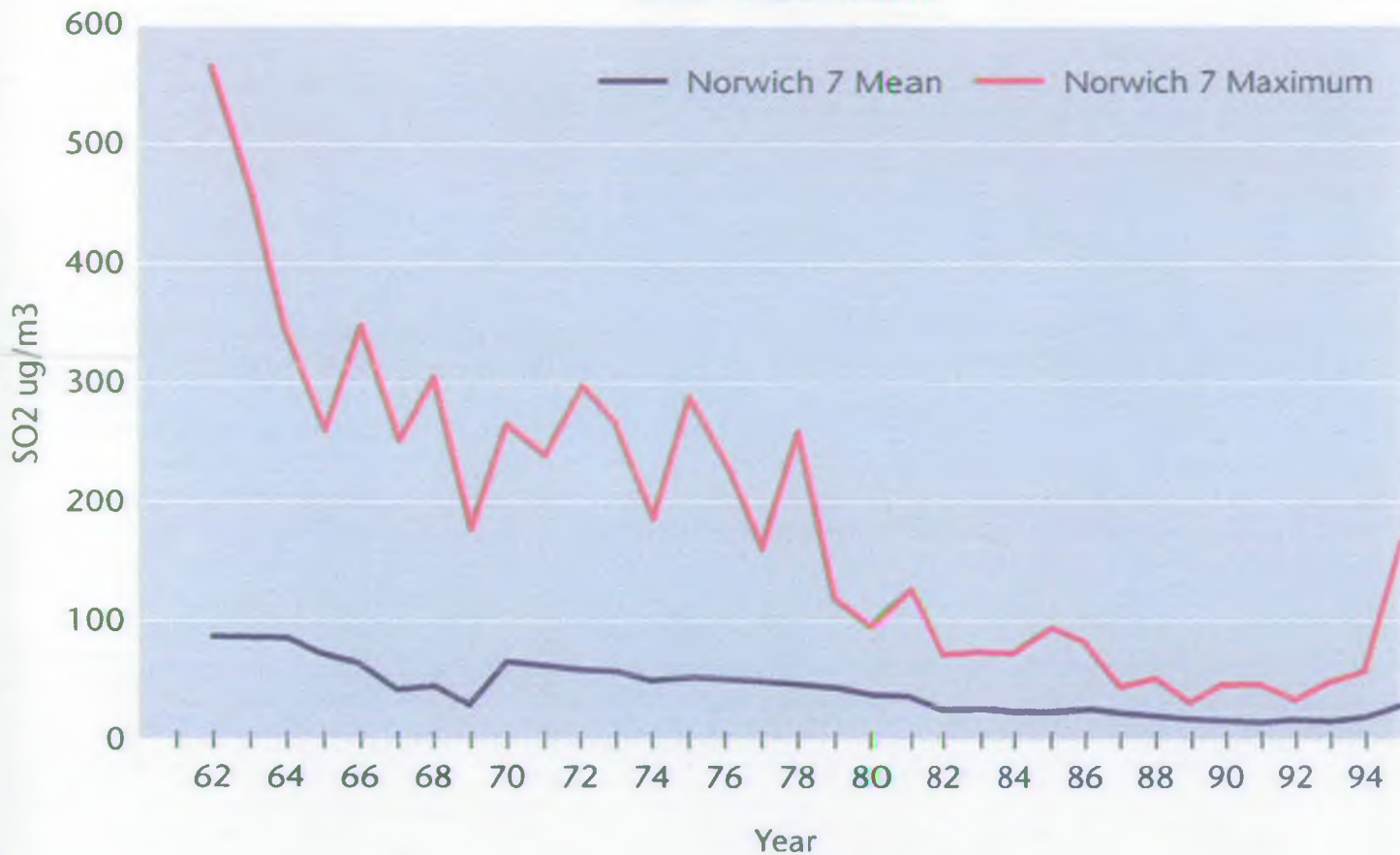
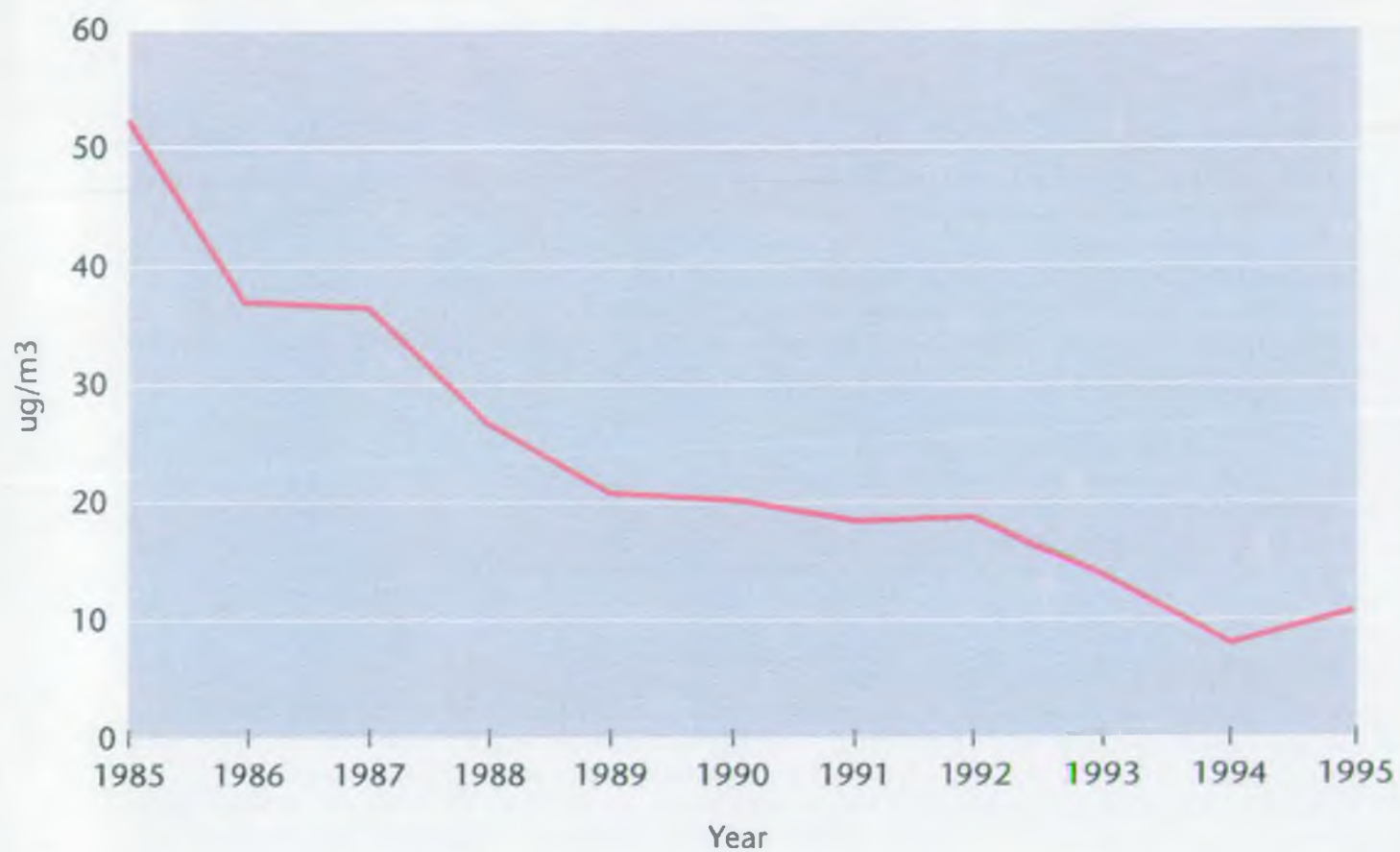


Figure 6 - Southend On Sea 2, SO<sub>2</sub> Long Term Trends in Annual Mean and Maximum





Figure 7 - Cardington SO<sub>2</sub> Annual Mean Data 1985 - 1995



## 2.6 ACID DEPOSITION AND CRITICAL LOADS

### 2.6.1 THEORY AND DEFINITIONS

Critical loads and levels were developed to provide the basis for an effects based approach to pollution control. In 1991 the Department of the Environment set up the Critical Loads Advisory Group (CLAG) to co-ordinate research into all aspects of critical loads and levels and also to provide advice on the most appropriate methods to use. Data presented in this report follows exactly the approved methodology published by CLAG.

A distinction must be maintained between the critical load which relates to deposition of a pollutant and the critical level which relates to concentration of the pollutant in the atmosphere. A critical load is defined as *"a quantitative estimate of exposure to one or more pollutants below which significant harmful effects on sensitive elements of the environment do not occur according to present knowledge"*. A critical level is defined as *"the concentration in the atmosphere above which direct adverse effects on receptors such as plants, ecosystems or materials, may occur according to present knowledge"*.

A critical load or level requires the definition of a sensitive receptor and an understanding of how the pollutant operates. A pollution load in excess of the critical load (or level) is termed the *"exceedance"*. The exceedance will vary from place to place, changes may be rapid and discontinuous or slow and gradual.

Taken to its logical conclusion, a critical load and level could be developed for every possible pollutant and for every part of the biotic and abiotic environment. In practice most progress has been made in developing critical loads for the acidity caused by sulphur and nitrogen compounds affecting soils, freshwaters, vegetation and the built environment. Most progress with critical levels has been made for the impact of sulphur and nitrogen oxides on vegetation, although some progress has also been made on critical levels for ozone.

Because of a lack of experimental data and other uncertainties in the direct and indirect impact of pollutants on sensitive receptors, research has, in the past, been directed towards different "Levels" of detail. For example, the critical load for acidity on soils has been estimated from: mineralogy and weathering rates, mass balance modelling of soil chemistry and dynamic modelling of soil chemistry. Although research and discussion continues at all levels of complexity empirical estimates of critical load based on mineralogy and weathering is currently the standard method.

### 2.6.2 MODELLING ACID DEPOSITION

Deposition rates have been estimated using the Hull Acid Rain Model (HARM). HARM is a Lagrangian statistical model designed to estimate annual pollutant levels and loads across the whole UK. It includes a detailed description of the chemical processes which occur, but models the effects of changes in meteorology in a more straight forward manner. Deposition rates have been modelled for 1995 and a map of non-marine sulphur deposition is presented.

The data acknowledgement for this map is Hull and Edinburgh Universities.

### 2.6.3 CRITICAL LOADS AND EXCEEDANCES

#### Critical Load of Acidity for Soils

The critical load of acidity for soils is based on the mineralogy and weathering rates of the dominant soil series in each one kilometre grid cell. Within each one kilometre cell there may be pockets of much more sensitive soils. The critical load is set to prevent acidification of the soil. The empirical map used for this work (Hornung et al, 1995) does not take any of the following into account: the probable management of the land for agriculture (including liming etc.), the acidity produced in the soil-plant system by the uptake of base cations and the potential neutralising effect of atmospheric inputs of calcium and magnesium.

In the Anglian Region the main area with low critical loads is around Thetford Forest where the shallow free draining soils have little buffering capacity and low weathering rates. There are also low critical loads along the Suffolk coast and around Norwich.

Under the current pollution load the critical load for acidity of soils is predicted to be exceeded around Thetford and the Suffolk coast.

The data acknowledgement for the map of critical loads for soils is Critical Loads Advisory Group Soils Sub-Group. The data acknowledgement for the map of critical loads exceedance is Hull and Edinburgh Universities/ Critical Loads Advisory Group Soils Sub-Group.

#### Critical Load of Sulphur for Freshwaters

In the estimate for critical load for freshwaters results from the diatom model have been used (CLAG, 1995). The diatom model is based on the identification of different species of diatom in lake sediments. From the relative



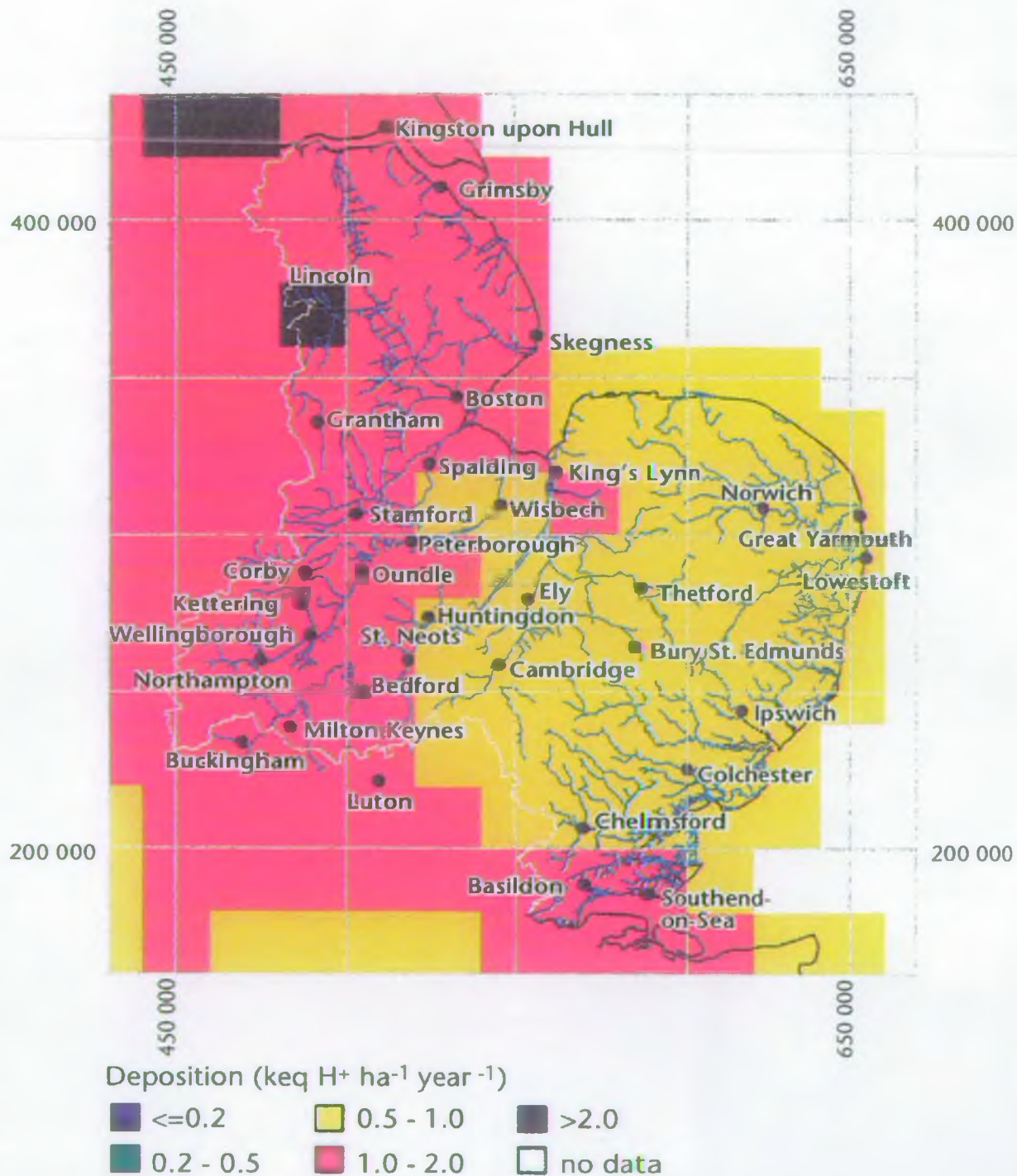
abundance of different species of diatom's, changes in the acidity of the lake water can be inferred for historical periods. A qualitative assessment of the water body which is most likely to be sensitive to acidification was used to select a single sampling point in each 10 kilometre cell. The critical load of a single sampling point is used for mapping the critical load class for the entire 10km square. However, the catchment of the water sampled may be only a few square kilometres and, therefore, the critical load value may not be representative for all waters in the grid square. A steady state water chemistry model has been developed but results from it are not presented here.

Under the current pollution load the critical load for acidity of freshwaters is predicted not to be exceeded.

The data acknowledgement for the map of critical loads for freshwaters is Critical Loads Advisory Group Freshwaters Sub-Group. The data acknowledgement for the map of critical loads exceedance is Hull and Edinburgh Universities/ Critical Loads Advisory Group Freshwaters Sub-Group.



# HARM 10.4 Modelled Current Non-Marine Sulphur Deposition for the Anglian Region

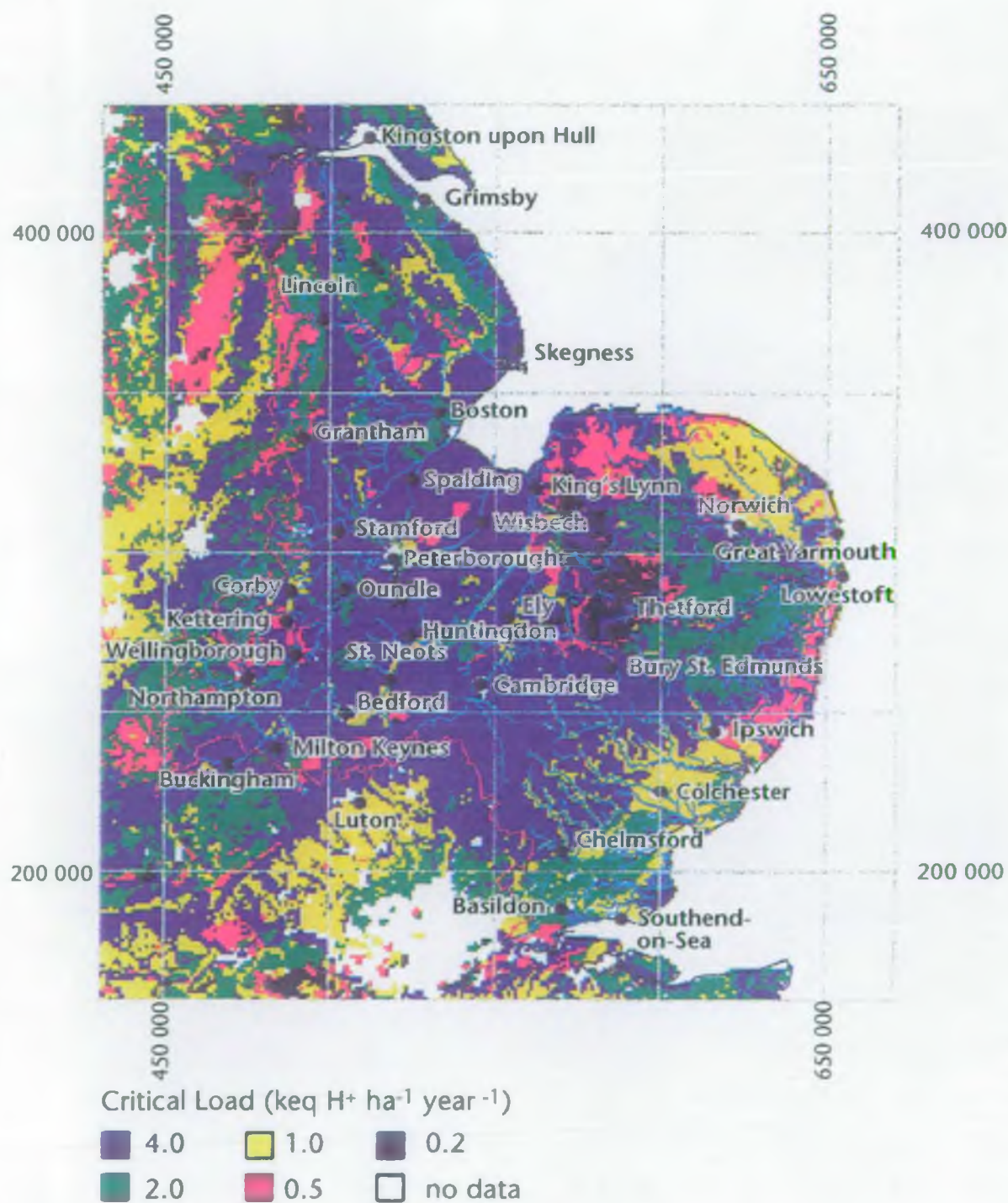


Critical Loads Mapping and Data Centre, ITE Monks Wood  
Data acknowledgement: Hull and Edinburgh Universities

February 1997



# 1km Empirical Critical Loads of Acidity for Soils for the Anglian Region



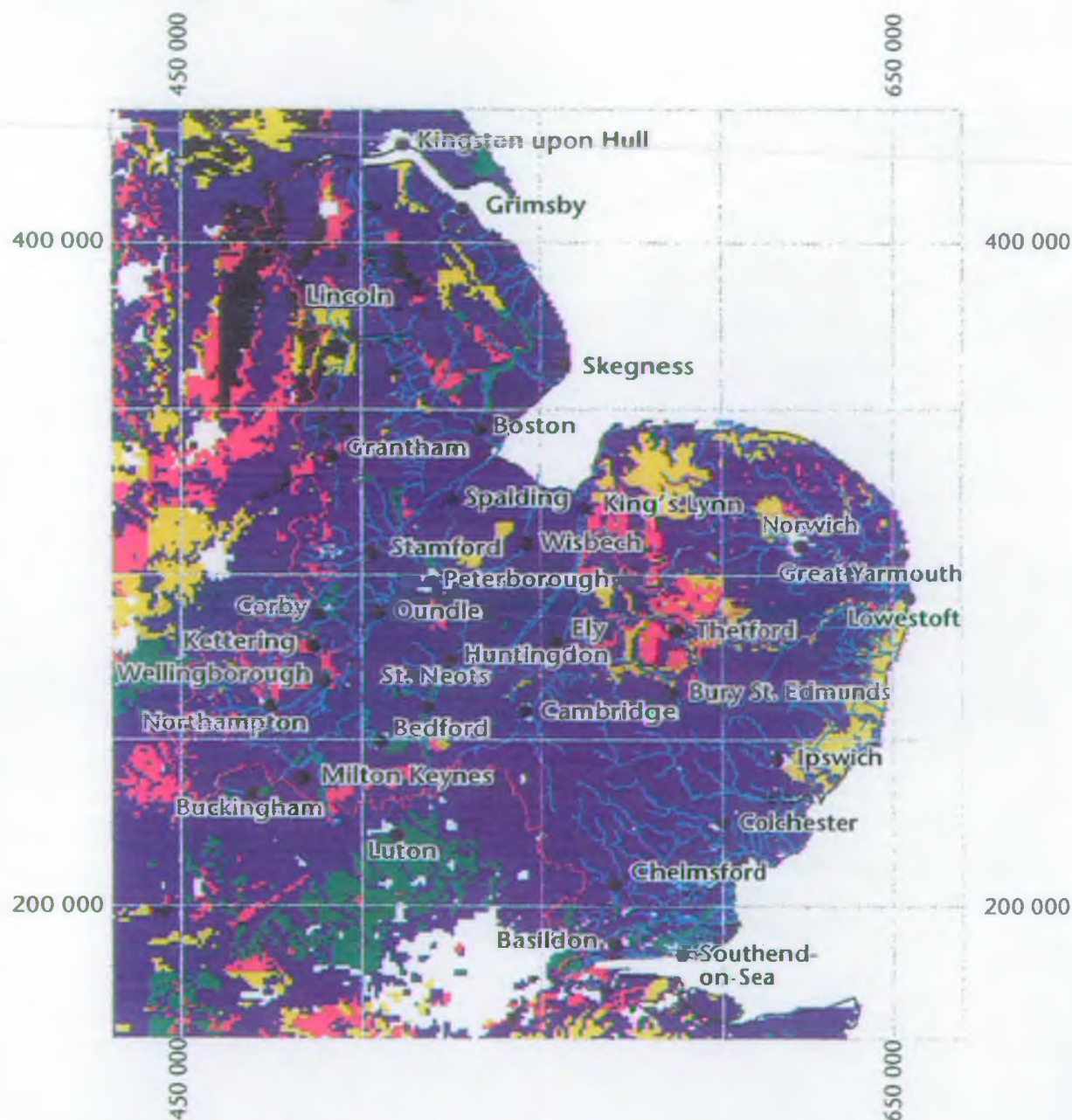
Critical Loads Mapping and Data Centre, ITE Monks Wood

February 1997

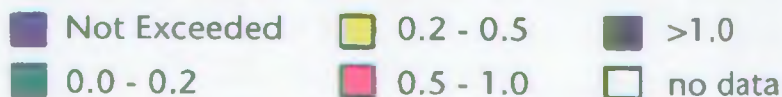
Data acknowledgement: Critical Loads Advisory Group Soils Sub-Group. Copyright: NERC



# Exceedance of Empirical Critical Loads of Acidity for Soils by HARM 10.4 Modelled Current Non-Marine Sulphur Deposition for the Anglian Region



Exceedance ( $\text{keq H}^+ \text{ha}^{-1} \text{year}^{-1}$ )



— Anglian Region Boundary      — Rivers      — Coastline

Critical Loads Mapping and Data Centre, ITE Monks Wood

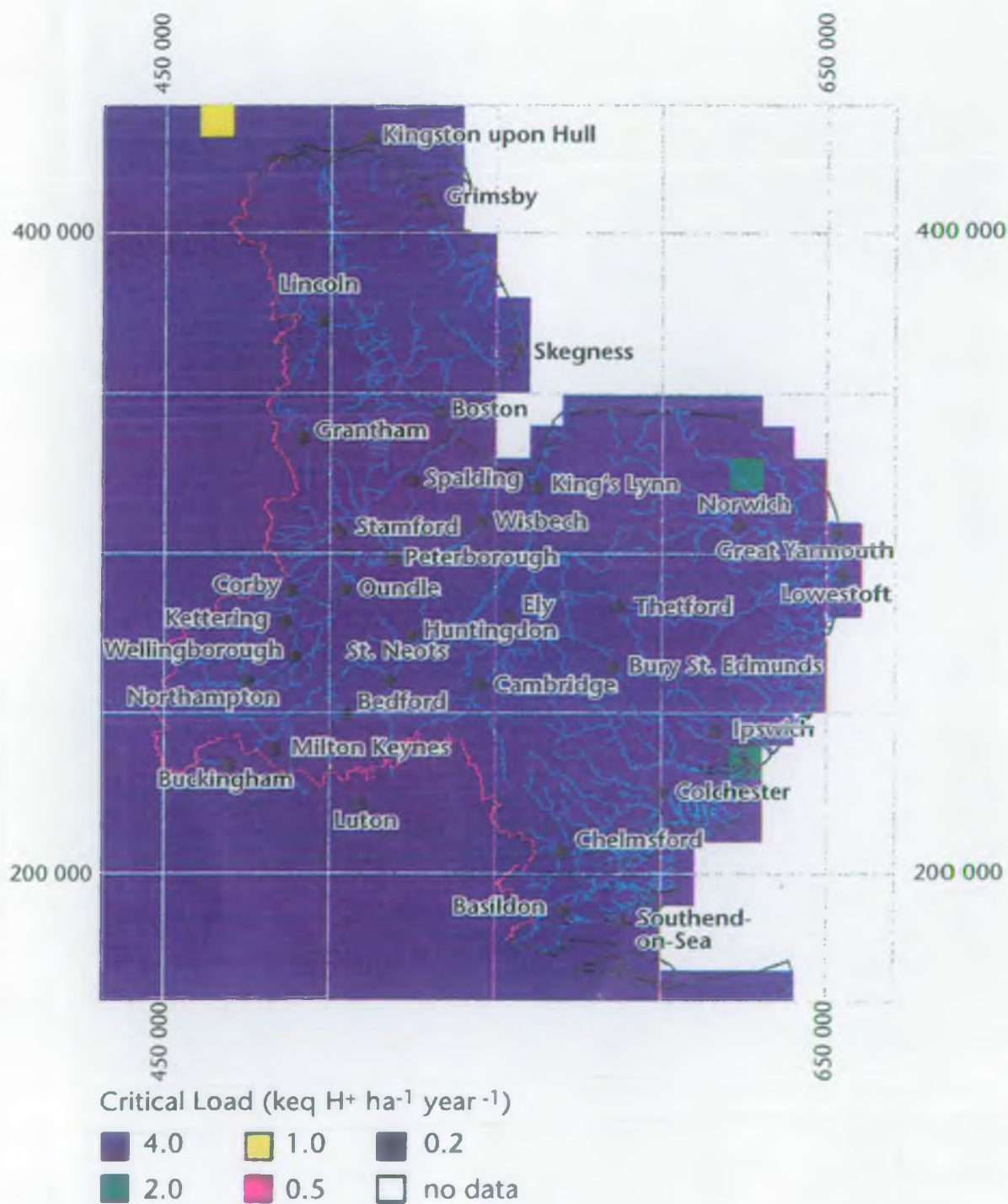
February 1997

Data acknowledgement: Hull and Edinburgh Universities

Critical Loads Advisory Group Soils Sub-Group



# 10km Critical Loads of Sulphur for Freshwaters - Diatom Model for the Anglian Region



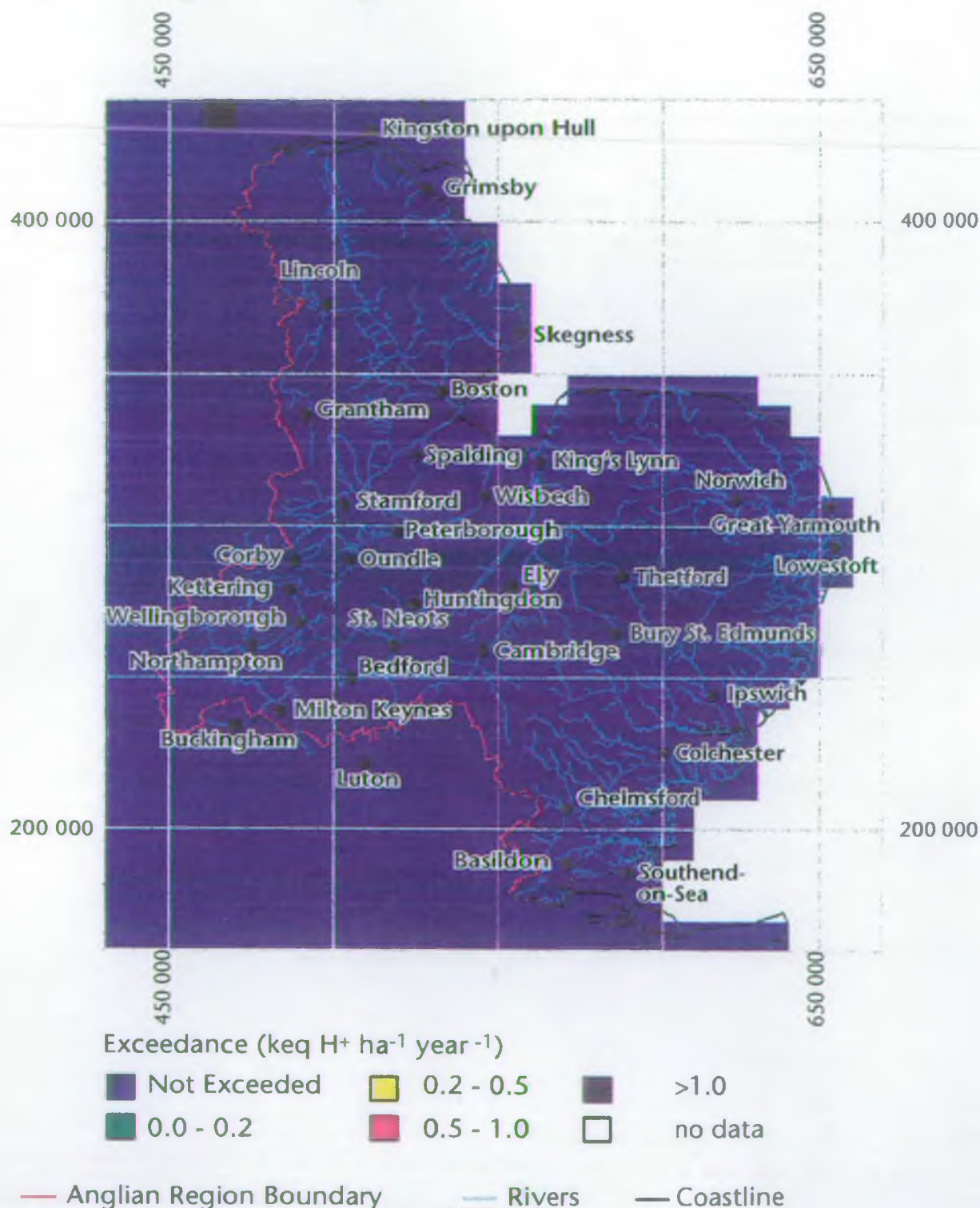
— Anglian Region Boundary      — Rivers      — Coastline

Critical Loads Mapping and Data Centre, ITE Monks Wood

February 1997

Data acknowledgement: Critical Loads Advisory Group Freshwaters Sub-Group

# Exceedance of Critical Loads of Sulphur for Freshwaters by HARM 10.4 Modelled Current Non-Marine Sulphur Deposition for the Anglian Region



Critical Loads Mapping and Data Centre, ITE Monks Wood

February 1997

Data acknowledgement: Hull and Edinburgh Universities

Critical Loads Advisory Group Freshwaters Sub-Group



### 3. ANGLIAN REGION IPC EMISSIONS

#### 3.1 INTEGRATED POLLUTION CONTROL [IPC]

Since 1991, major industrial processes in the UK have been regulated under a system known as Integrated Pollution Control [IPC]. The Environment Agency issues a single authorisation covering releases to air, water and land.

The environment is not divided up neatly into compartments of land, air and water. These media constitute an integrated whole and in many cases a choice can be made as to whether to direct a discharge to land, air or water or to a combination of them. The Royal Commission on Environmental Pollution recognised this in their Fifth Report in 1976. They developed the concept of 'best practicable environmental option', [BPEO], recommending that each industrial process should be looked at as a whole and that the pattern of discharges should be selected to ensure the best overall outcome for the environment. This might, for instance, involve an increase in emissions to air to avoid a much more damaging discharge to water, or vice versa.

Interpretation of the data from the CRI depends on an appreciation that the IPC system was implemented in industry tranches, commencing in 1991, over a period of approximately five years. Figure 8 shows the increase in processes regulated by IPC for the Anglian Region of the Environment Agency. Similar data for the Fuel and Power sector is shown in Figure 9.

The system of Integrated Pollution Control was established under the Environmental Protection Act 1990 and is administered by the Environment Agency in England and Wales.

Its main features are:-

- all the most seriously polluting processes, including those with significant emissions to air, those which discharge specified dangerous substances to water or which generate significant quantities of 'special wastes', are prescribed for IPC;
- the operator of any such process needs prior authorisation from the Environment Agency.

In granting and reviewing the authorisation, the Environment Agency:-

- enforces any existing release limits or environmental quality standards;
- requires the application of 'best available techniques not entailing excessive cost' [BATNEEC] firstly to prevent or, if prevention is not possible, to minimise the most polluting substances at source and to ensure that any residual releases are rendered harmless to the environment;
- considers different disposal options to establish what is best for the environment as a whole;
- consults other bodies responsible for environmental protection;
- ensures that applications for IPC authorisation are advertised and representations from the public taken into account;
- requires operators to pay for their authorisation as part of the "polluter pays" principle;
- ensures that details of the application, authorisation, information on compliance and any enforcement action taken are held in registers to which the public has free access.

This approach to pollution control has some very important features:-

- it is essentially precautionary in character because it requires the minimisation of pollution at source;
- it operates through control of the technology of the whole process, and as the technology improves [or as the perception of risk changes], so the standards must improve; and
- it requires co-operation and collaboration between industry and the regulator.

The processes under IPC are categorised into:-

- Fuel production, combustion and associated processes, e.g. oil refineries, power stations.
- Metal production and processing, e.g. steelworks.
- Mineral Industries, e.g. cement kilns.
- Chemical Industry.
- Waste disposal and recycling, e.g. incineration.
- Other industries, e.g. paper and pulp.

A separate regime for controlling emissions to air alone, known as Local Authority Air Pollution Control [LAPC], from generally less polluting processes was also introduced under the Environmental Protection Act 1990. For such processes, local authorities [district and borough councils, and in some cases, port health authorities] are enforcing authorities.

## 3.2 REGIONAL SULPHUR DIOXIDE EMISSIONS IN THE NATIONAL CONTEXT

Current interest in ambient air quality is focused on the eight substances contained in the Government's National Air Quality Strategy, one of which is sulphur dioxide. In addition to concern regarding the health effects of SO<sub>2</sub> [upon which the NAQS SO<sub>2</sub> objectives are based], there is a UK government commitment to the UNECE Second Sulphur Protocol, which requires the reduction of National emissions of sulphur dioxide, in order to prevent acidification of soils and waters due to acid rain.

UNECE Second Sulphur Protocol, UK Emissions Reduction Targets:-

EMISSIONS	1980	2000	2005	2010
SO <sub>2</sub>	Baseline	50% reduction	70% reduction	80% reduction

UNECE is developing an Acidification Strategy which in future will also take account of oxides of nitrogen.

Key influences in meeting the above sulphur emissions reduction targets are:-

- i Switch from coal to heavy fuel oil and gas;
- ii Completion of current flue gas desulphurisation [FGD] programme;
- iii BATNEEC under IPC and Best Available Technology [BAT] under Integrated Pollution Prevention and Control [IPPC].

The above factors converge in electricity supply industry. The Protocol contains specified emission limit values for combustion plant constructed after 1995 and for existing plant rated at > 500 MW [thermal]. Current IPC improvement programmes based on fuel changes and FGD will deliver substantial SO<sub>2</sub> emission reductions.

Sources of UK SO<sub>2</sub> air pollution 1994 [NETCEN, HMIP, Central Statistical Office] :-

Source of SO <sub>2</sub> emission	% of total emissions
Road transport	2
Other transport	2
Electricity supply	65
Other industry	24
Domestic	3
Other	3

80% of SO<sub>2</sub> emissions are regulated under IPC. The majority of the remainder is regulated under LAPC or the Clean Air Act 1993. The relative contributions of the IPC process types to total SO<sub>2</sub> emissions are presented in Figure 10. Approximately 86% of the SO<sub>2</sub> emissions from Anglian Region's IPC processes originate from Fuel & Power processes, such as coal fired electricity generation stations. The total emissions of SO<sub>2</sub> from all IPC processes in the Anglian Region are shown in Figure 11. This graph demonstrates that SO<sub>2</sub> emissions are within the limits set in the authorisation conditions and that regulation is being tightened by the reduction of emission limits being set.

Emissions projections suggest that the above targets for 2000 and 2005 will be met through review of the electricity supply industry and other industrial combustion plant in the UK. For the purposes of projection, it is assumed that IPC upgrading of processes other than electricity generation will result in such plant achieving the emissions standards currently required of new plant by 2005. By 1995 the UK emissions of SO<sub>2</sub> from large combustion plant had fallen by 55% relative to 1980. An example of the dramatic reduction of SO<sub>2</sub> from IPC processes in the Kings Lynn and West Norfolk District Council area is shown in Figure 12.

The UK Government is planning a review in 3 years time [to co-incide with the first review of the National Air Quality Strategy] and close monitoring of emissions.

Currently envisaged IPC upgrading alone will not achieve 2010 targets but advances in technology / control techniques [currently unforeseen] are likely to enable achievement of 2010 target. The Government is also keeping market based approaches under review.



There are proposals to:-

- revise the Large Combustion Plants Directive. Informal proposals in 1996 sought to establish revised emission limit values for new plant and new national ceilings for existing plant;
- adopt a directive on sulphur content of heavy fuel oil, jet fuel and bunker oil [heavy fuel oil accounts for approx. 21% of UK SO<sub>2</sub> emissions]. National sulphur projections do not take account of proposals to limit the sulphur content of heavy fuel oil. Formal proposals have not yet been published by the Commission but the draft proposals of 1994 proposed a 1% by weight limit on the sulphur content of heavy fuel oil;

The National Air Quality Strategy proposes a 100ppb SO<sub>2</sub> objective based on 15 min averaging period to be achieved with a 99.9% compliance rate. New measures under the National Air Quality Strategy may result in greater reductions at national emission levels. An example of SO<sub>2</sub> data for the one of the air quality monitoring stations in Anglian Region is shown in Figure 13, indicating that for the period of these data, the NAQS objective for SO<sub>2</sub> was achieved.

The Government is obliged to report annual emissions data from existing large combustion plant to the European Commission.

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### 3.3 INDUSTRY SECTORS

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#### 3.3.1 FUEL & POWER

The trend in total emissions of three substance groups, namely sulphur compounds, nitrogen compounds and particulates from the fuel and power processes is shown in Figure 14. The apparent increase in emissions over the period 1992 to 1995 is actually an increase in authorised emissions and reflects the increasing number of processes being dealt with under the IPC regulatory regime. Figure 15 illustrates the same data expressed as emissions per authorisation, as an attempt to take account for the increasing number of processes authorised under IPC. It is relevant to note that applications for IPC authorisation are determined according to local air quality criteria, rather than total mass emissions, though BATNEEC will inevitably deliver reductions in mass emissions.

The CRI has been interrogated to provide more specific examples of the contribution of particular types of process to overall emissions in the Anglian Region. These are illustrated by Figures 16 and 17. The combustion processes category is sub-divided into "conventional" boilers or furnaces and the gas turbine or compression engine types. These plots show that the emissions of particulates were reduced for both boilers and gas turbines over the period 1992 to 1995. It is also evident that in aggregate these processes are operating within authorised limits for emissions of particulates, sulphur compounds and nitrogen compounds. The gas turbine type of power generation is seen to contribute much less than the conventional combustion processes to overall emissions from IPC processes. There is no account taken for the relative thermal input of these processes in the presentation of these data here, though it is appropriate to note that CCGT [combined cycle gas turbines] are increasingly important in the generation of electricity in the Anglian Region and the UK in general and that their performance, certainly in terms of SO<sub>2</sub> and particulate emissions, is considered to be superior to current coal fired power stations.

#### 3.3.2 METAL PRODUCTION & PROCESSING

Integrated Pollution Control involves the control of releases to all environmental media, namely air, land and water. The importance of environmental media other than air for certain releases is illustrated in Figure 18. It can be seen that releases of metals, halogens and halogenated compounds are many times greater to water than to air.

#### 3.3.3 MINERALS

Major minerals processes such as cement works are regulated under IPC. Figure 19 summarises the emission to air from minerals processes, for nitrogen compounds, halogenated compounds and particulates. The apparent increase in emissions from 1993 to 1994 is due to more existing processes being authorised within the new IPC regulatory regime. The impact of improvement programmes and the application of BATNEEC then begins to manifest itself in the 1995 release data.

#### 3.3.4 CHEMICAL INDUSTRIES

The Environment Agency's Chemical Release Inventory is an important tool not only to track the emissions performance of individual Operators against their authorisation conditions, but also to assess the overall performance improvement of an industry sector. Figure 20 presents data relating to the release of oxidising agents to land and water. It shows that actual releases are well within authorised limits. There may be a case for further to reducing authorised limits, with a view to maintaining and improving the current performance of the chemical industries with respect to these releases.

#### 3.3.5 WASTE DISPOSAL AND RECYCLING PROCESSES

Waste disposal and recycling is an example of an industrial sector which has variable results relative to its authorised limits for 1995 releases. Figure 21 demonstrates that releases of nitrogen compounds, organic and metals to water

are within limits. Furthermore, emissions to air of sulphur compounds and nitrogen compounds are significantly below their limits [Figure 22], but the releases of oxides of carbon exceeded their authorised limits in 1995. Under such circumstances, the Agency's Inspectors enter into dialogue with Operators who are failing to meet their authorisation conditions. This may involve agreement of immediate remedial action, prohibition notices, enforcement notices and in some circumstances, prosecution.

### **3.4 LOCAL AUTHORITY AIR QUALITY MANAGEMENT STRATEGY**

Part IV of the Environment Act 1995 and the National Air Quality Strategy set out a new system of local air quality management, directed at protecting human health. Local authorities have the lead role in reviewing and assessing the quality of the air in their areas against statutory air quality objectives. However the IPC function of the Agency is expected to collaborate with the LAs in a number of ways: sharing monitoring and modelling data and expertise; providing information on Part A processes; engaging in consultation on the reviews, assessments and action plans; participating in local steering groups.

The following sections show examples of IPC release data for three counties within Anglian Region. It should be borne in mind that the primary responsibility for air quality management lies with the District or Borough Councils. Nevertheless, County Councils will have an important role to play and in general co-operation between authorities will be encouraged for the facilitation of the achievement of air quality objectives. The data discussed here serve to illustrate some of the variations between LA areas, depending on the location of IPC processes. The interpretation of this data requires recognition that air emissions do not respect local authority boundaries and may be relevant to LAs beyond the boundary of the LA where the release occurs. In this context air dispersion modelling is exploited by Inspectors and Operators in controlling emissions.

#### **3.4.1 CAMBRIDGESHIRE**

The National Air Quality Strategy is based on eight substances, namely benzene, 1,3-butadiene, carbon monoxide, lead, nitrogen dioxide, ozone, fine particulates and sulphur dioxide.

The emissions of five of these substances are presented in Figure 23 for the four LAs within Cambridgeshire which have IPC authorised processes releasing these substances. In terms of mass released it can be seen that Fenland and Huntingdon have the greatest releases of sulphur dioxide, whilst Peterborough has the largest carbon monoxide and nitrogen oxides [NO<sub>x</sub>] releases. In order to further interpret this data it would be necessary to review and assess the impact of traffic contributions to local emissions and air quality, which often far outweigh industrial emissions.

#### **3.4.2 NORFOLK**

Norfolk is predominantly rural in nature, though some major industrial processes, regulated by IPC, are located in this county. The greatest IPC emissions of NAQS substances are sulphur dioxide and NO<sub>x</sub> in Kings Lynn & West Norfolk and carbon monoxide in North Norfolk [Figure 24].

The IPC emissions to air in Kings Lynn and West Norfolk are further analysed in Figures 25 to 27. These graphs show the decline of NO<sub>x</sub>, carbon monoxide and particulates IPC emissions between 1993 and 1995. That is, the contribution of IPC processes to ambient air quality has reduced significantly since the introduction of the IPC regulatory regime.

#### **3.4.3 NORTHAMPTONSHIRE**

The relative importance of Corby as a source of IPC emissions of carbon monoxide and NO<sub>x</sub> is demonstrated by Figure 28. Information of this type would allow LAs to focus their review and assessment activity of the IPC contribution to air quality to those areas which have the major emissions, in much the same way evaluation of traffic emissions would focus on major conurbations and roads.



Figure 8 - IPC Authorisations, Anglian Region

ALL INDUSTRY SECTORS

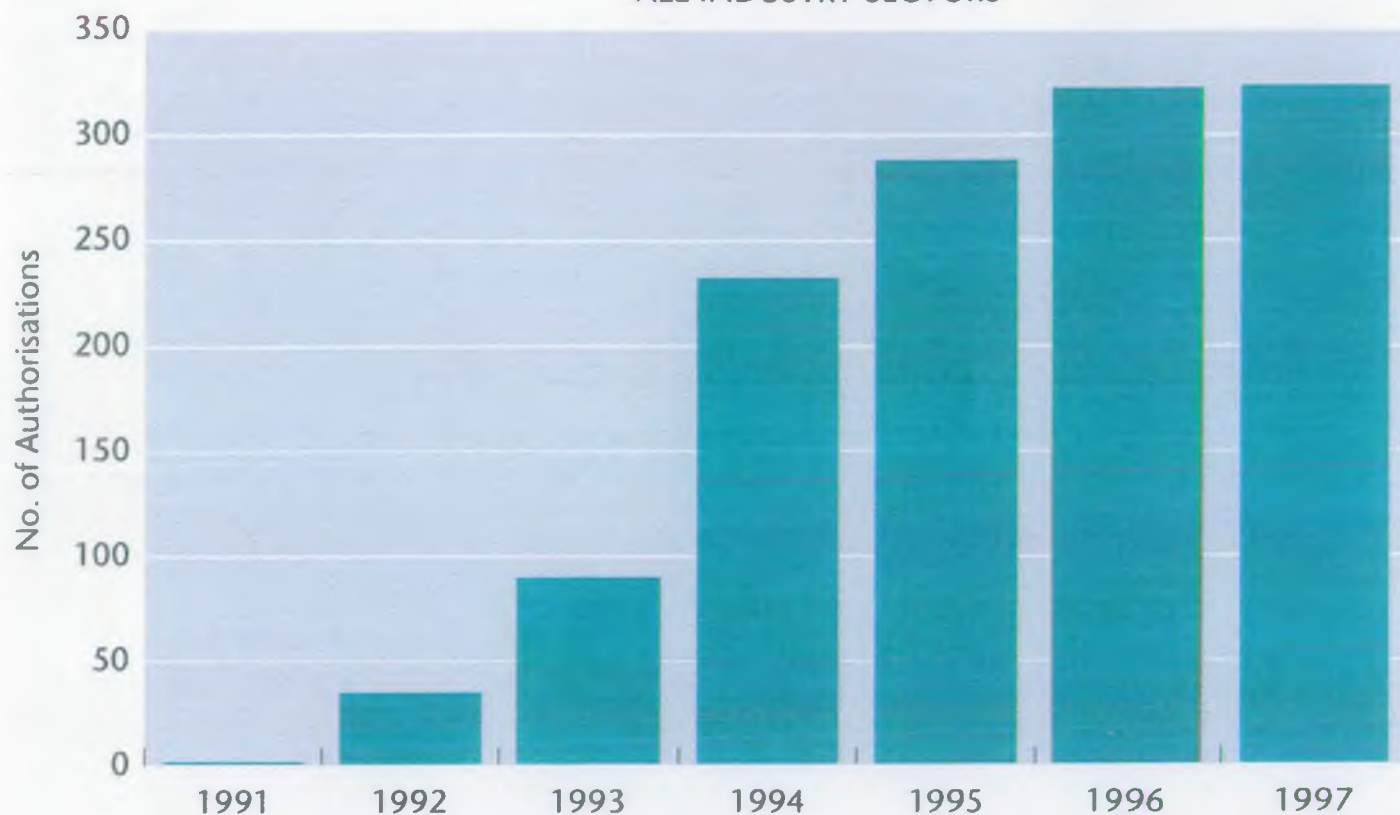


Figure 9 - IPC Authorisations, Anglian Region

FUEL & POWER SECTOR

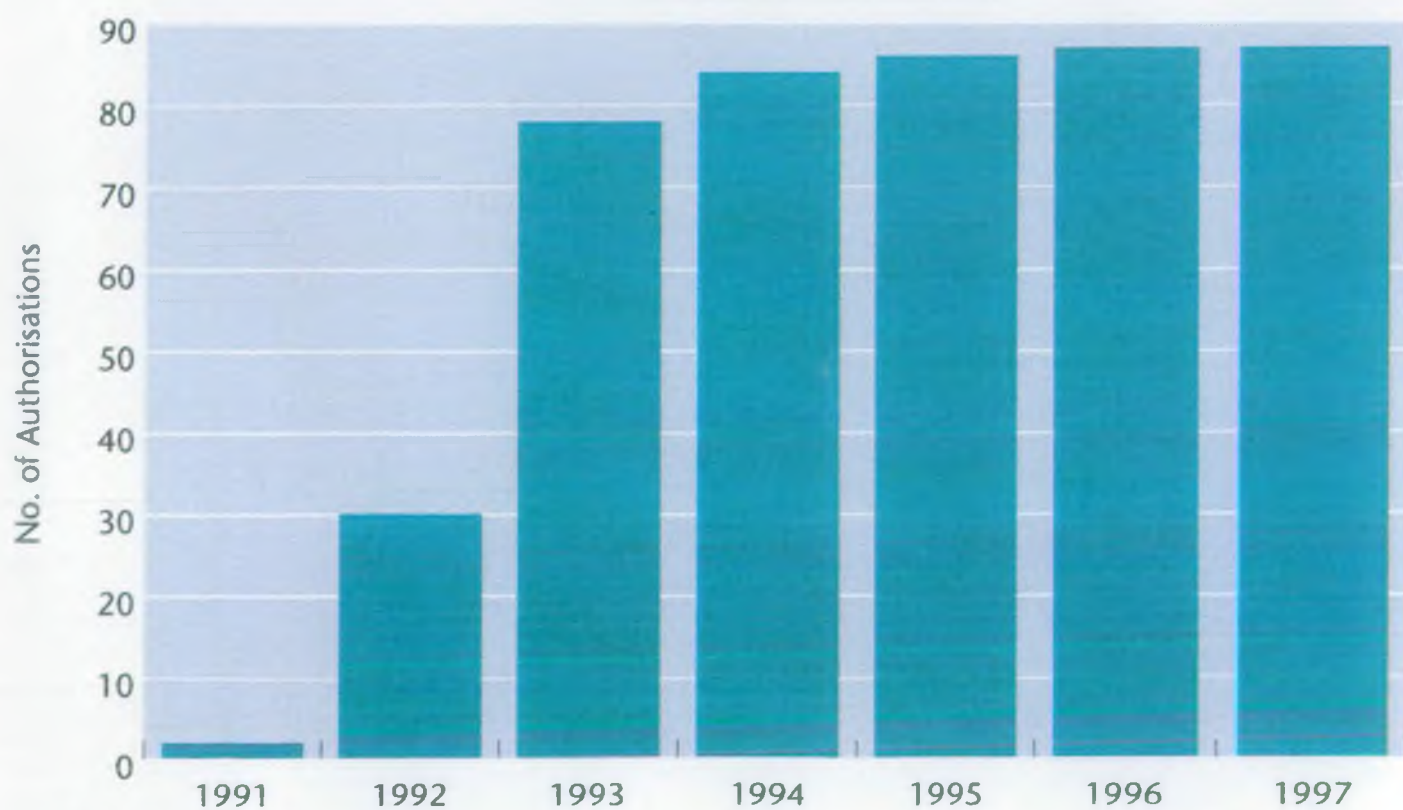


Figure 10 - SO<sub>2</sub> Emissions  
ANGLIAN IPC, 1995

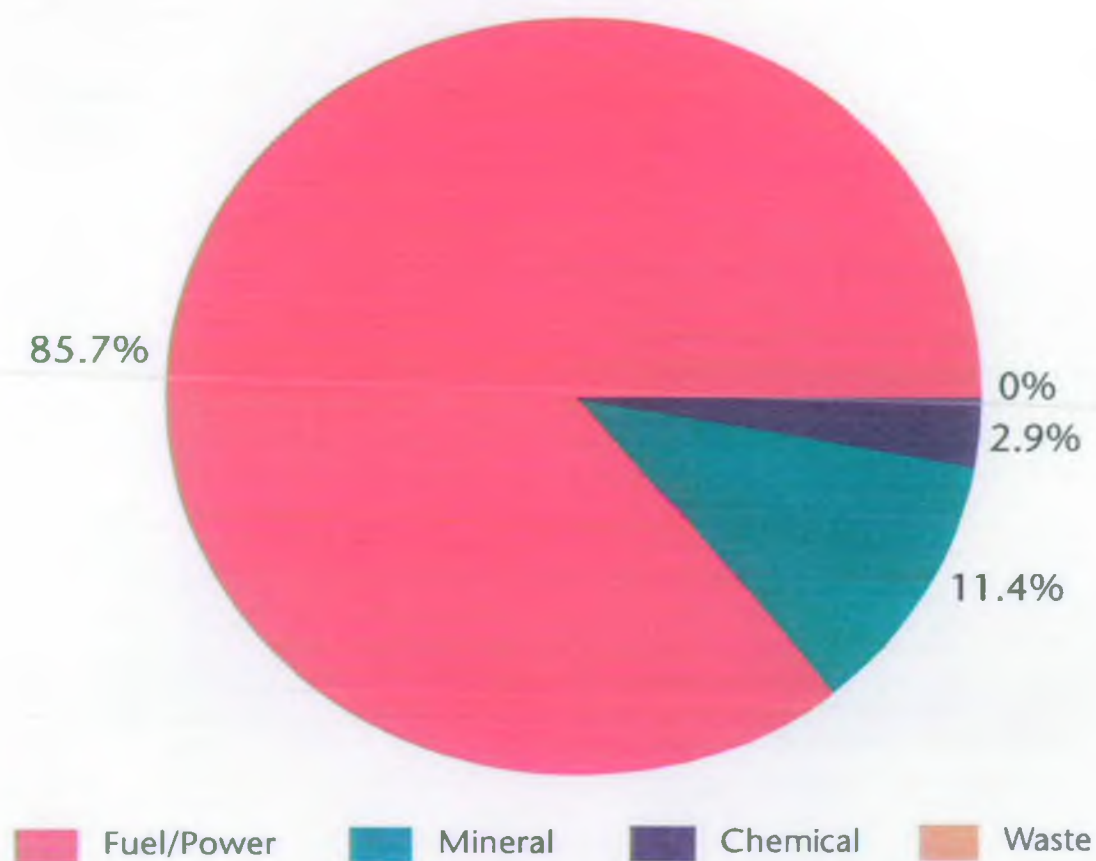


Figure 11 - SO<sub>2</sub>, Anglian Region  
TOTAL IPC PROCESSES

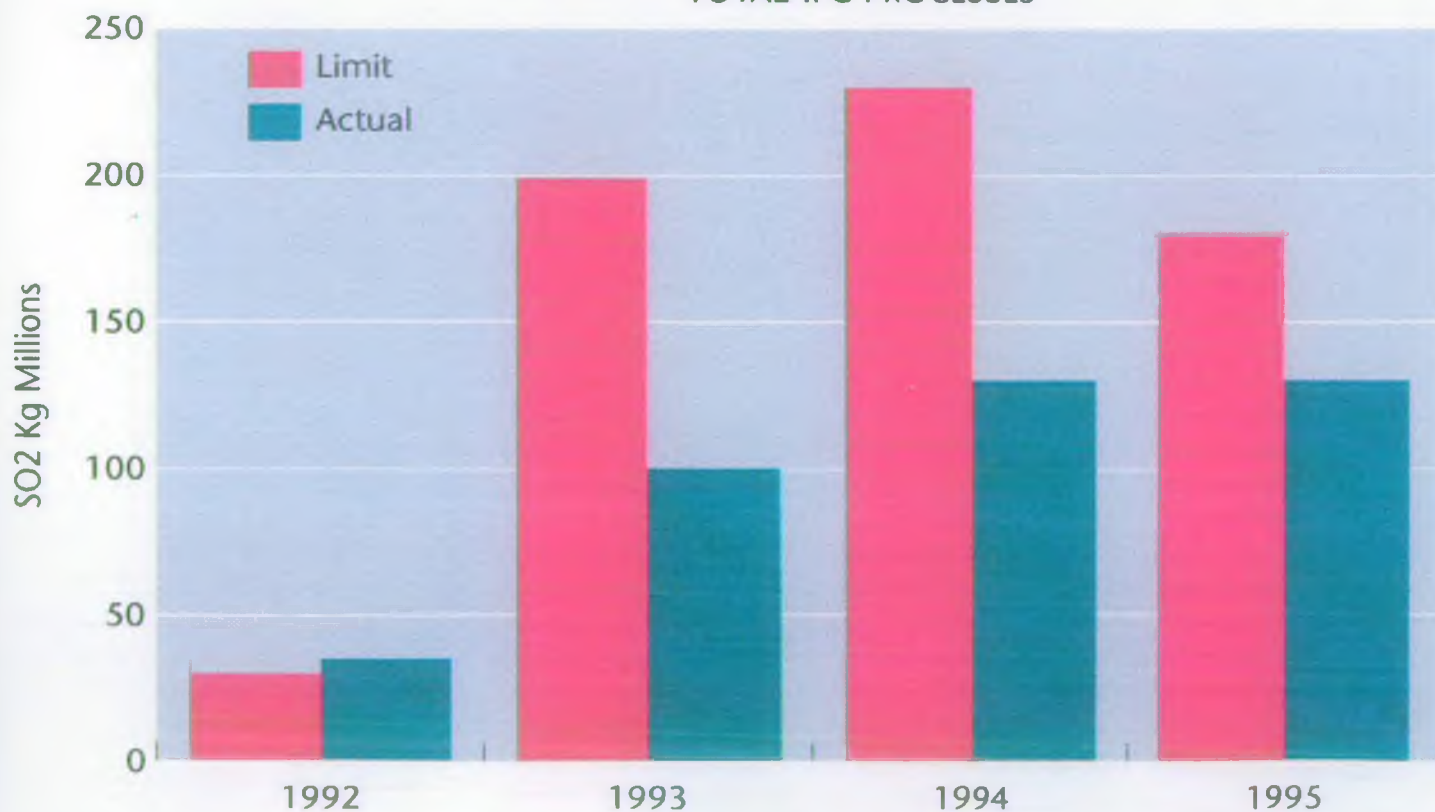




Figure 12 - King's Lynn & West Norfolk

IPC PROCESSES

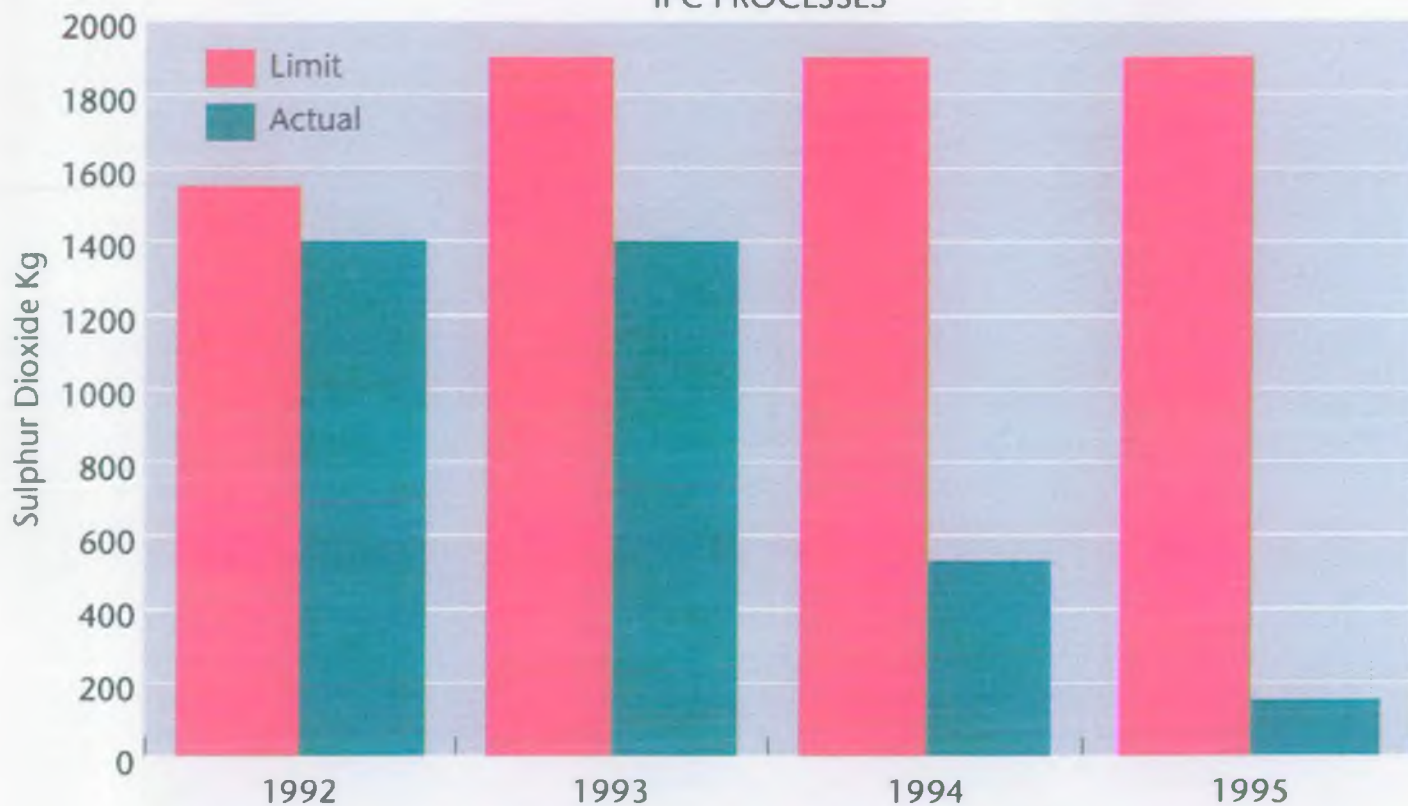


Figure 13 - Thurrock SO2

NAQS 100 ppb 99.9%ile BY 2005

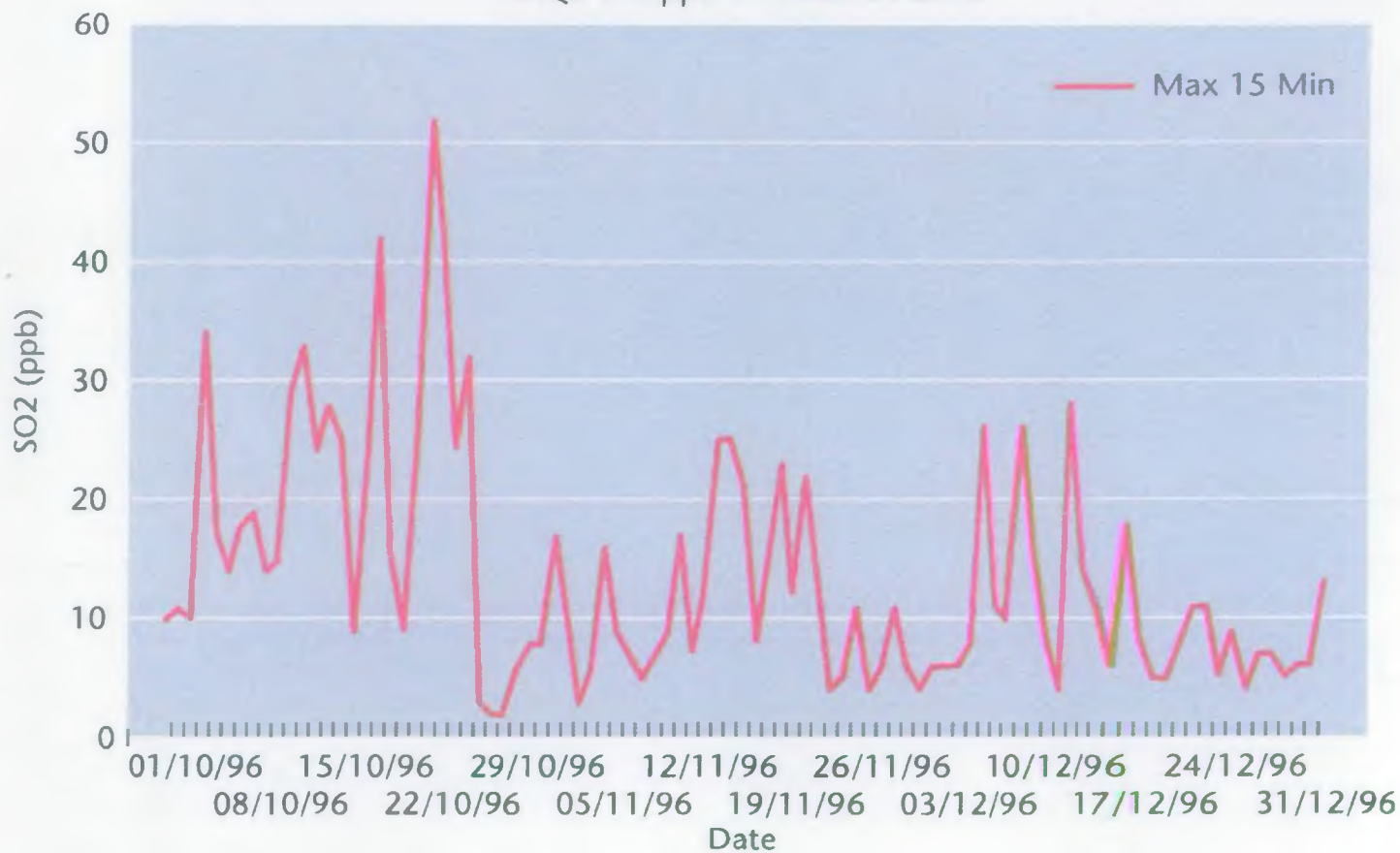




Figure 14 - Fuel & Power, Anglian Region

IPC EMISSIONS TO AIR

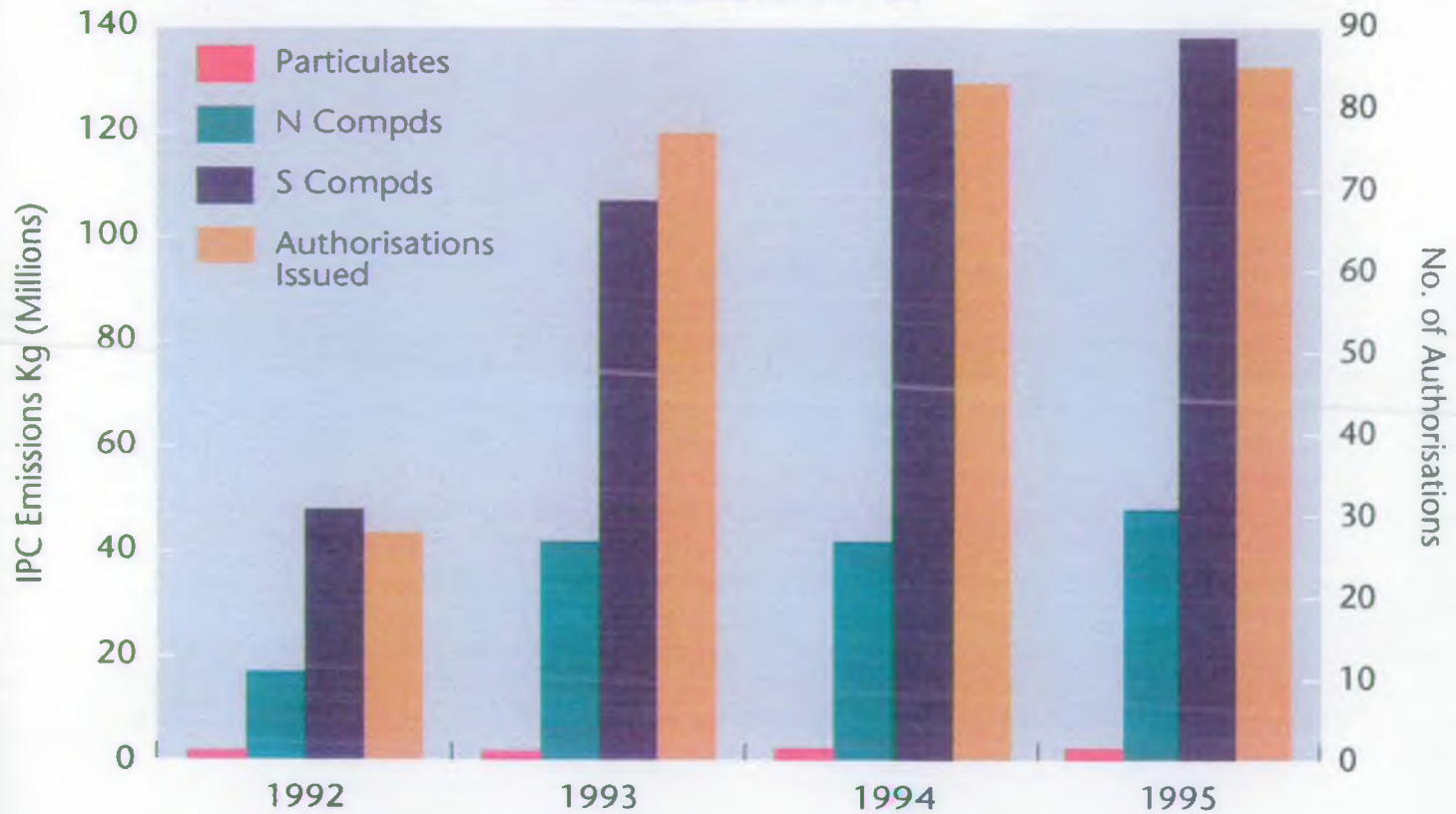


Figure 15 - Emissions per Authorisation, Anglian Region

FUEL & POWER SECTOR

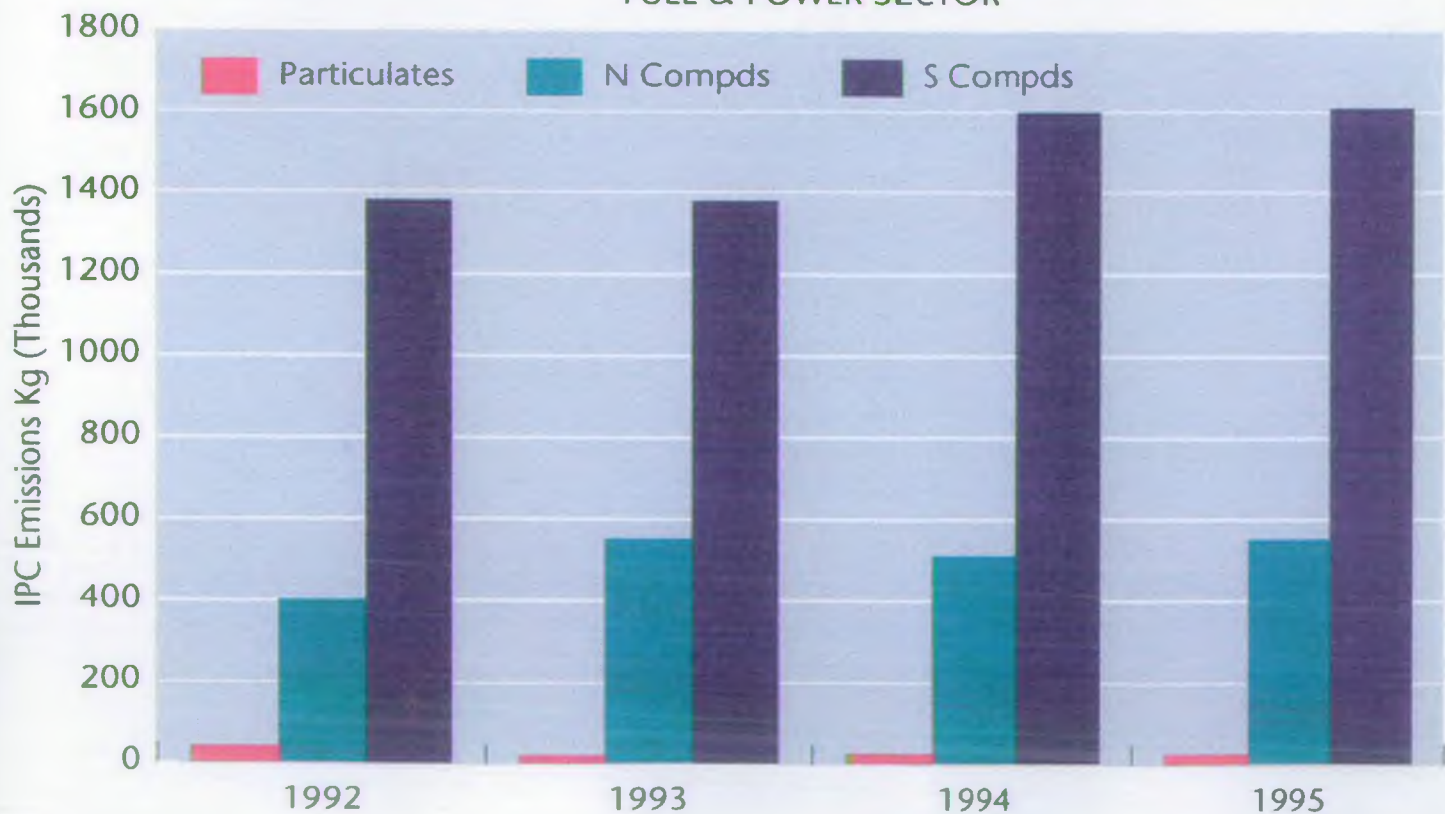


Figure 16 - IPC Particulates to Air, Anglian Region

COMBUSTION PROCESSES

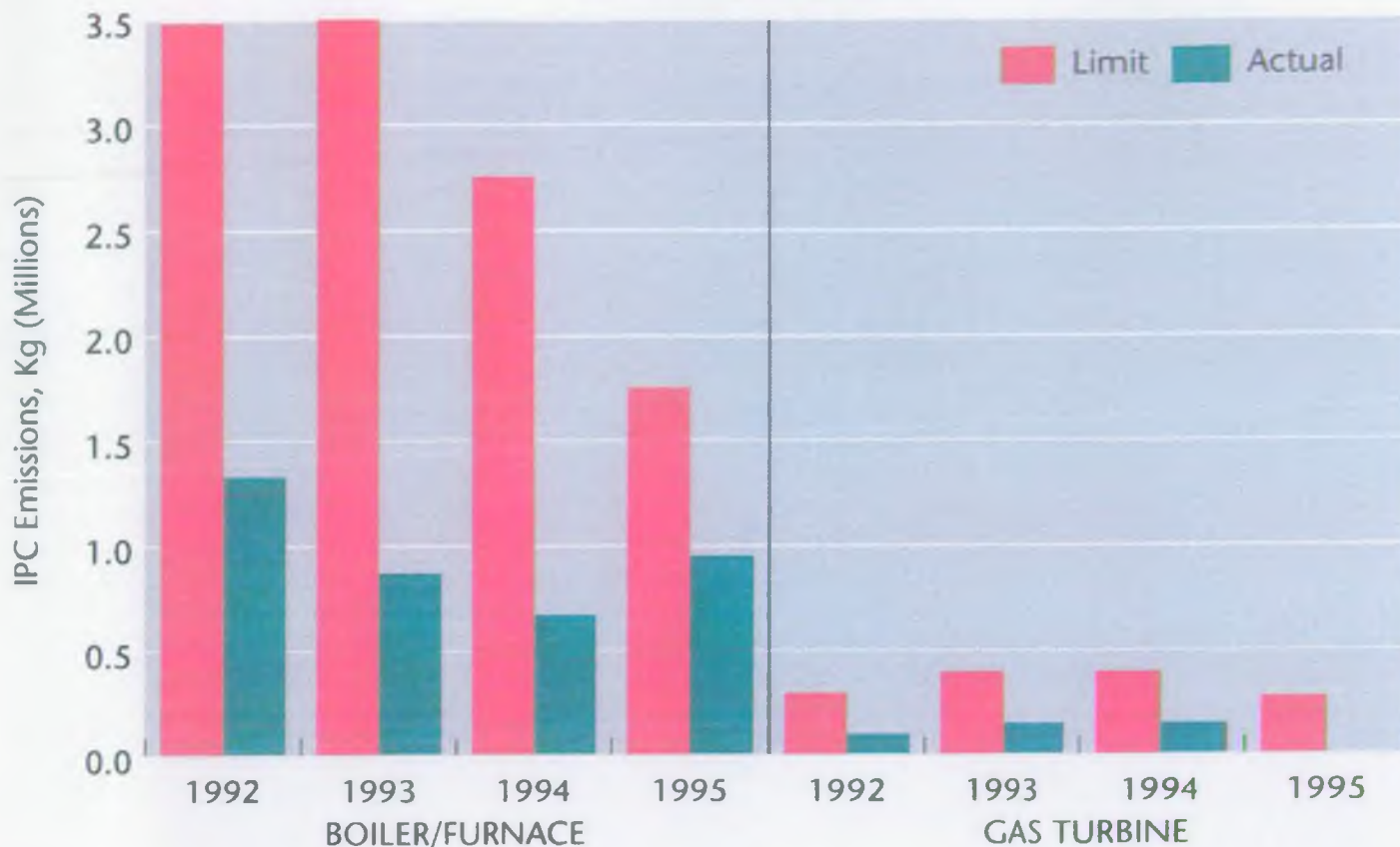


Figure 17 - IPC Particulates to Air, Anglian Region, 1995

COMBUSTION PROCESSES

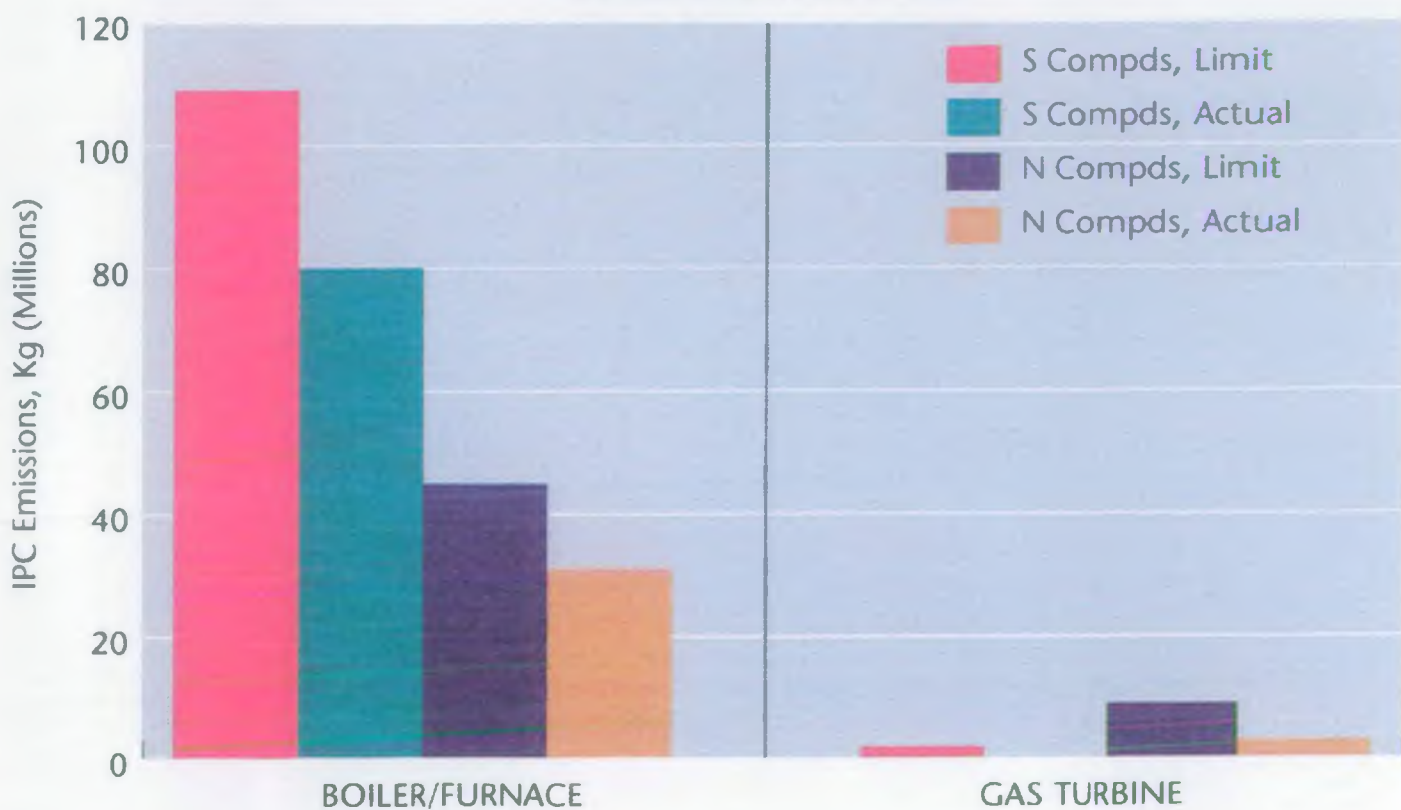




Figure 18 - Metal Prod'n/Processing, Anglian Region  
EMISSIONS TO AIR AND WATER, 1995

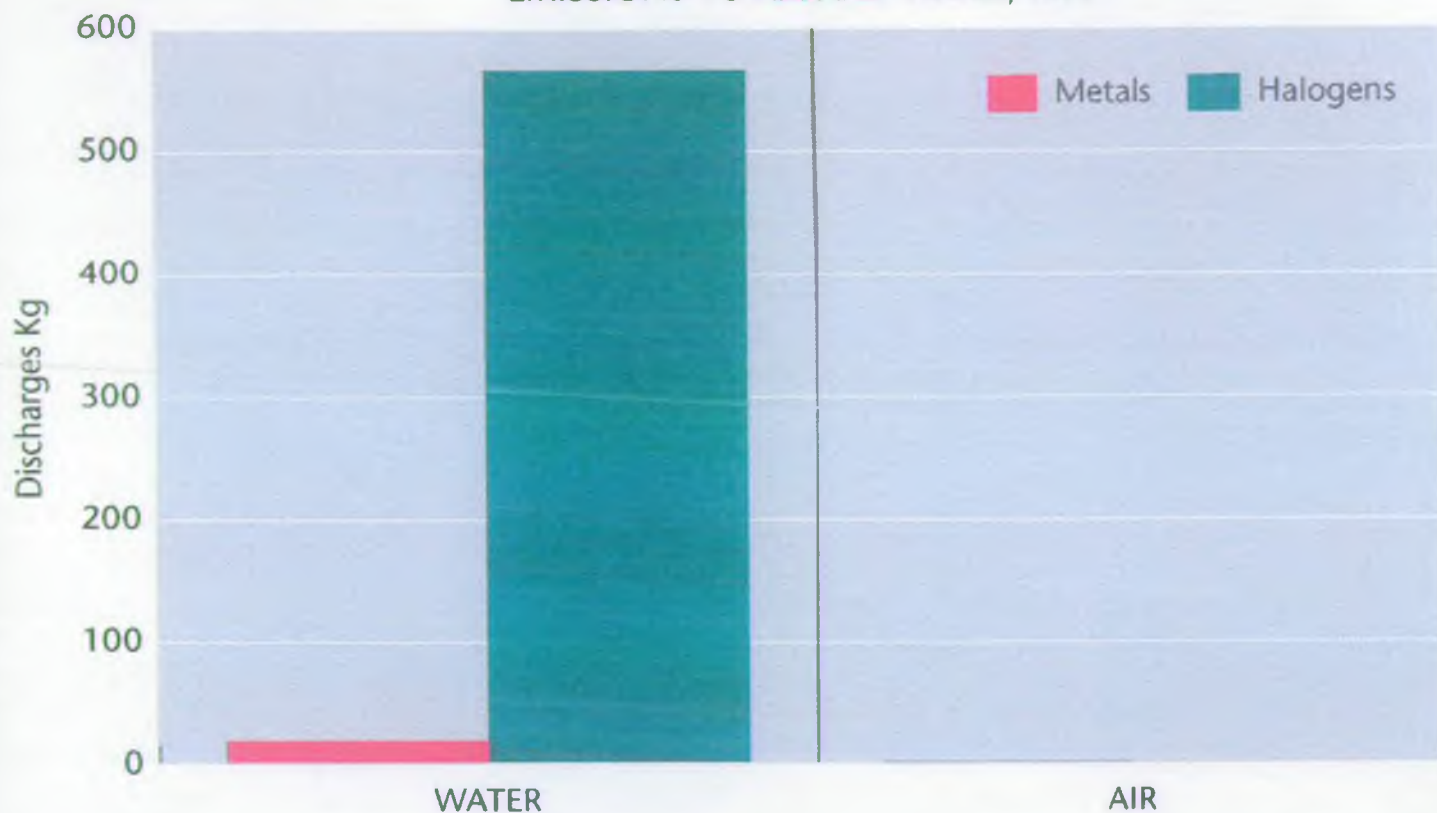


Figure 19 - Mineral Industries, Anglian Region  
EMISSIONS TO AIR

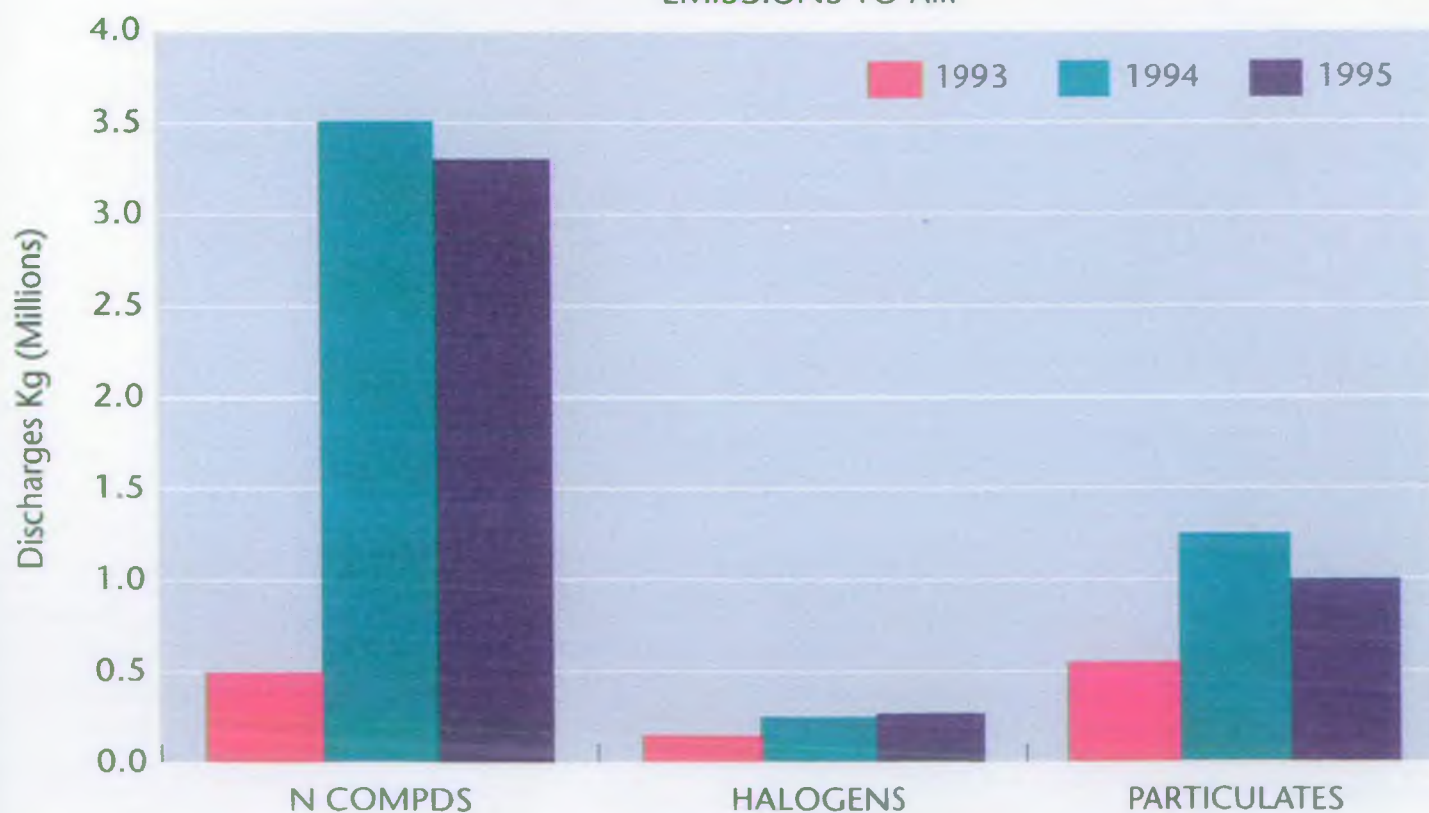




Figure 20 - Chemical Industries, Anglain Region

OXIDISING AGENT RELEASES, 1995



Figure 21 - Waste Disposal/Recycling Processes England & Wales 1995

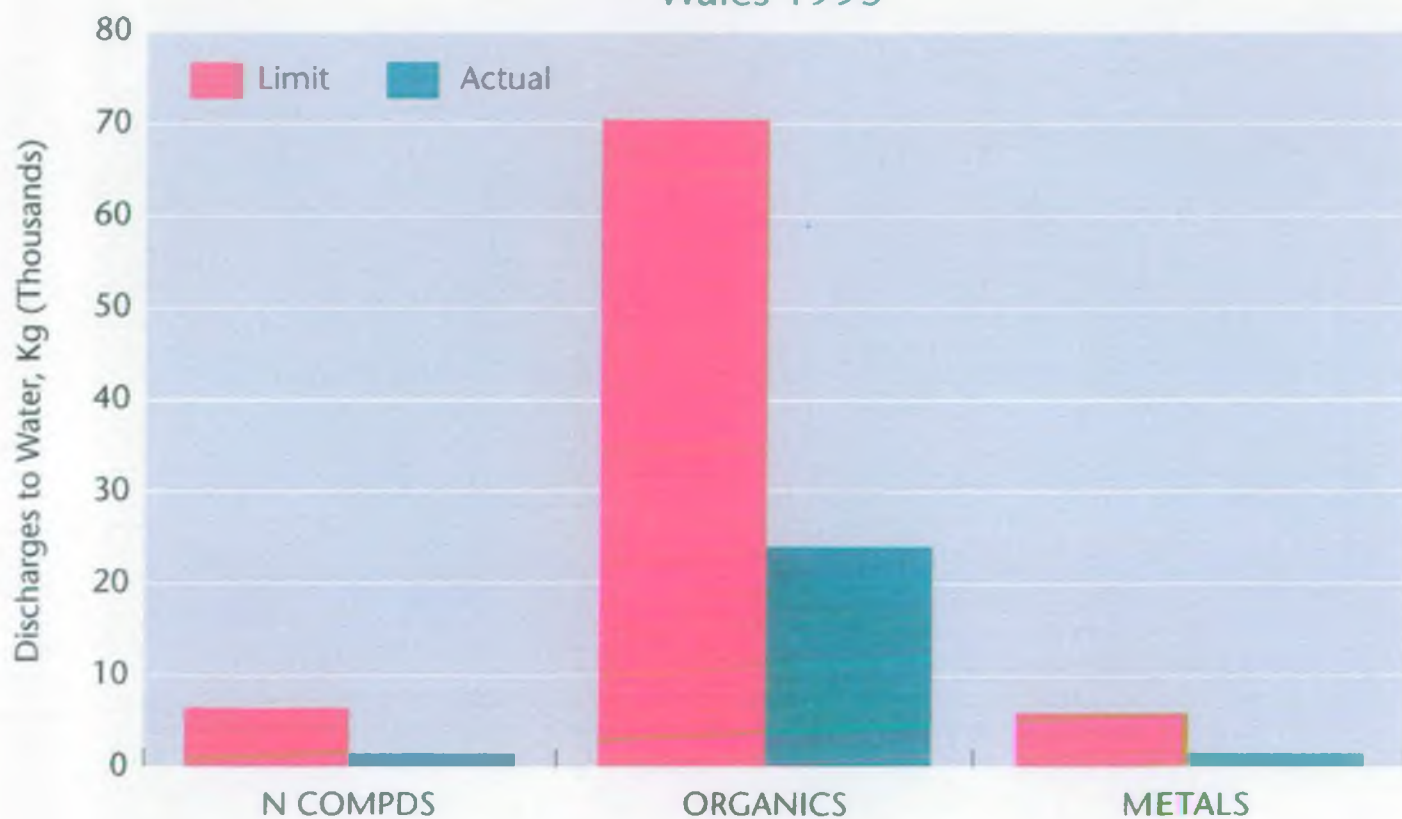


Figure 22 - Waste Disposal/Recycling Processes

ANGLIAN REGION 1995, EMISSIONS TO AIR

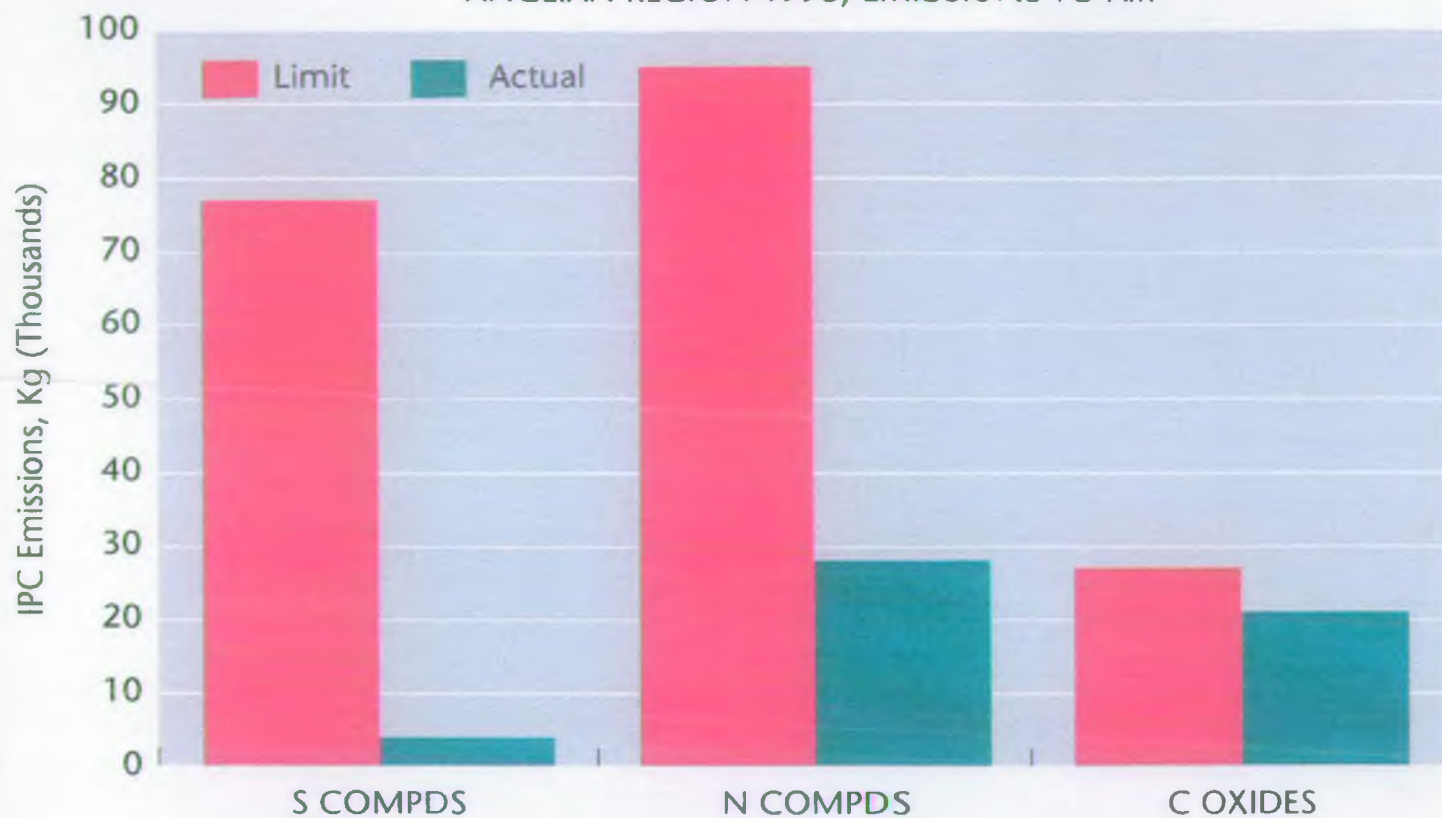


Figure 23 - IPC Emissions to Air, Cambridgeshire, 1995

AQMS SUBSTANCES

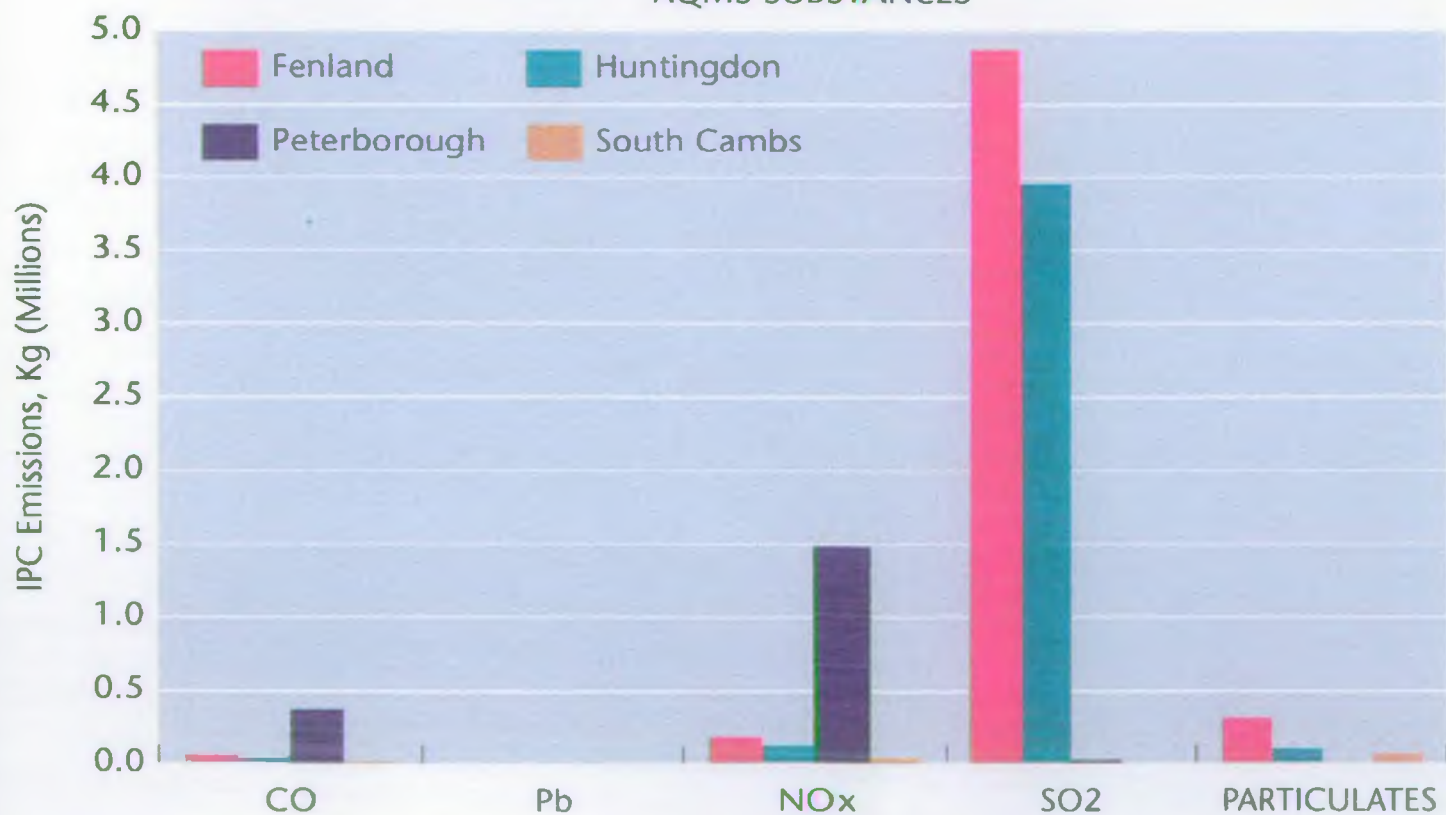




Figure 24 - IPC Emissions to Air, Norfolk, 1995

AQMS SUBSTANCES

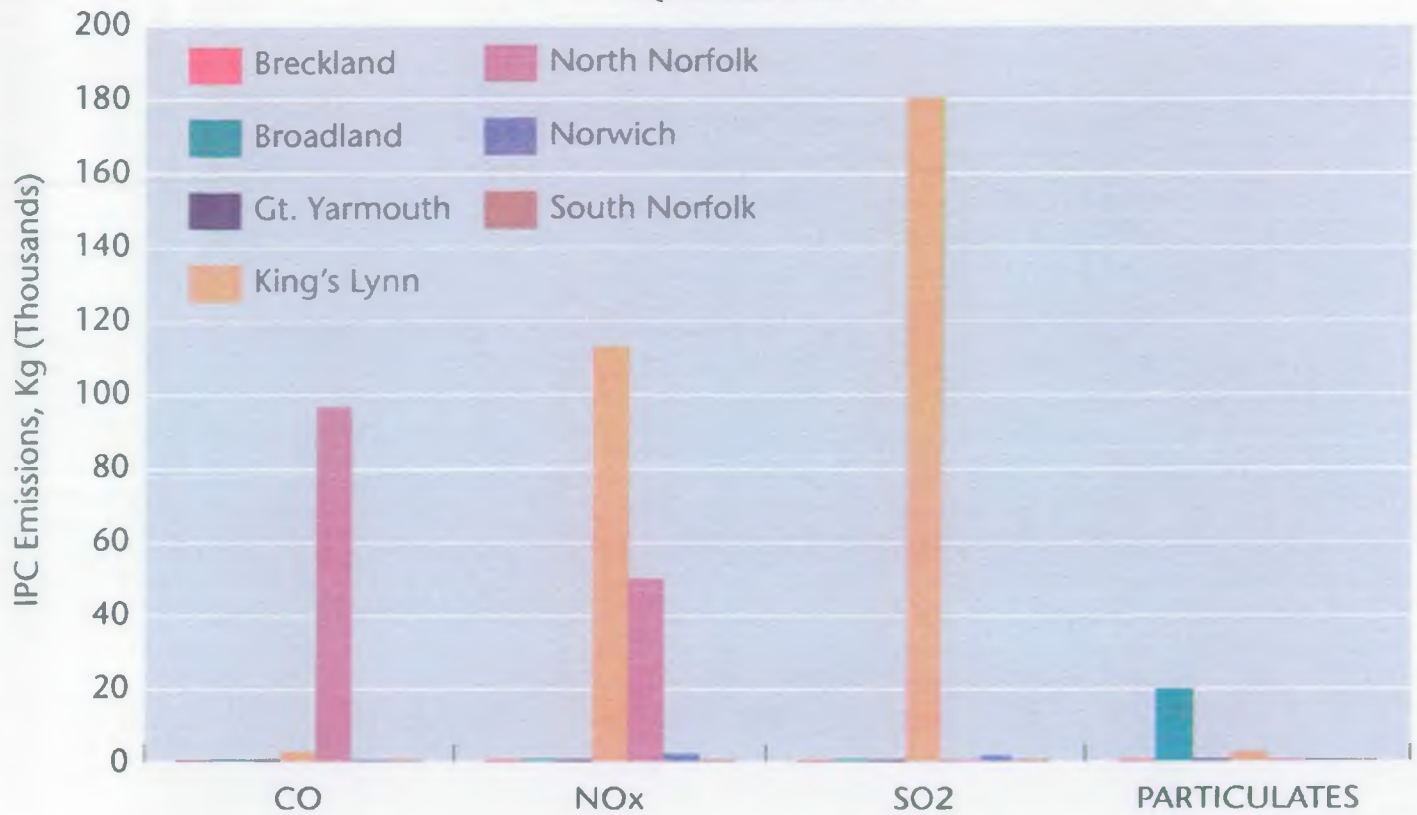


Figure 25 - NOx King's Lynn & West Norfolk

IPC PROCESSES

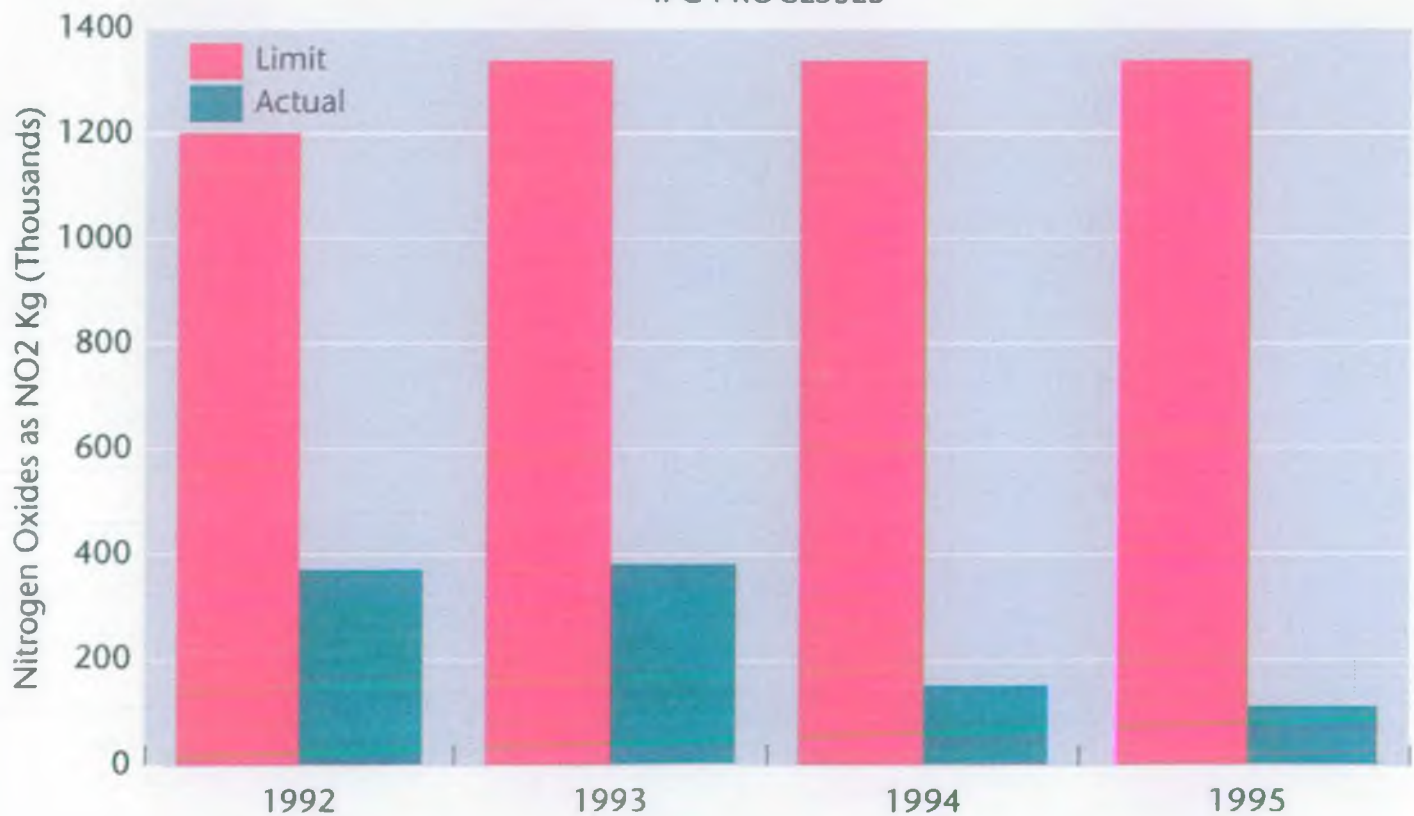


Figure 26 - CO King's Lynn & West Norfolk  
IPC PROCESSES

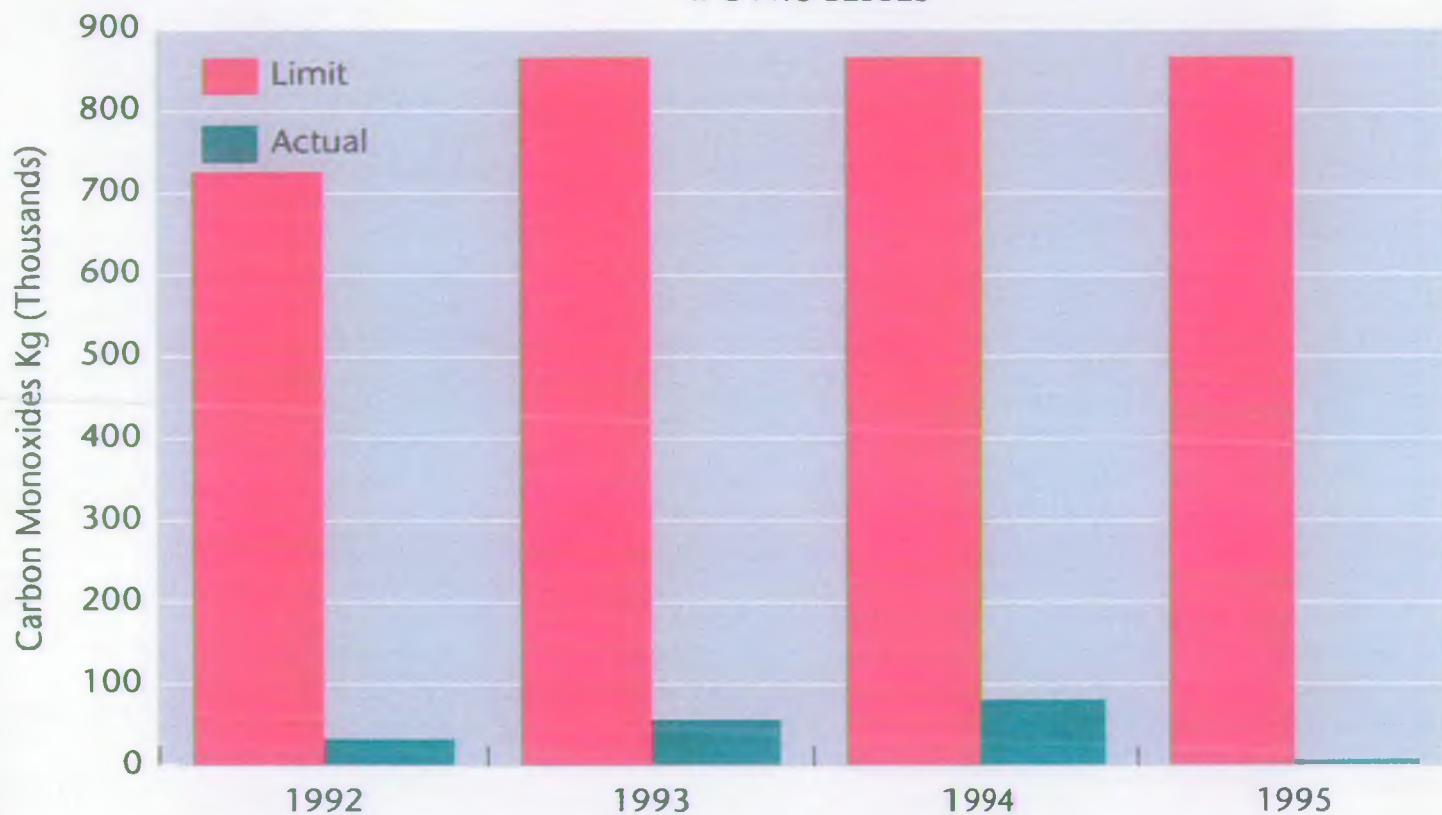


Figure 27 - Particulates - IPC Proceses  
KING'S LYNN & WEST NORFOLK

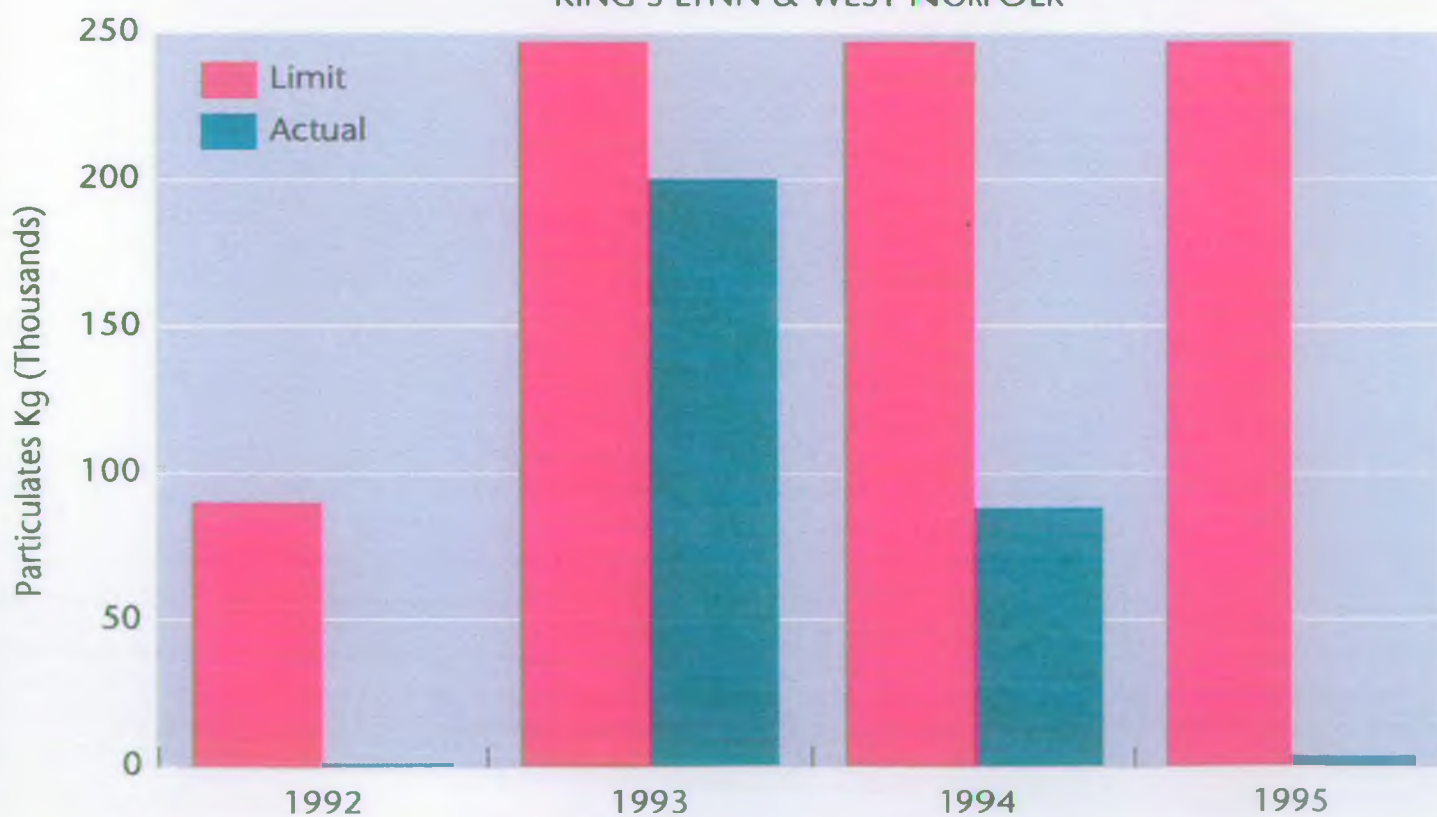
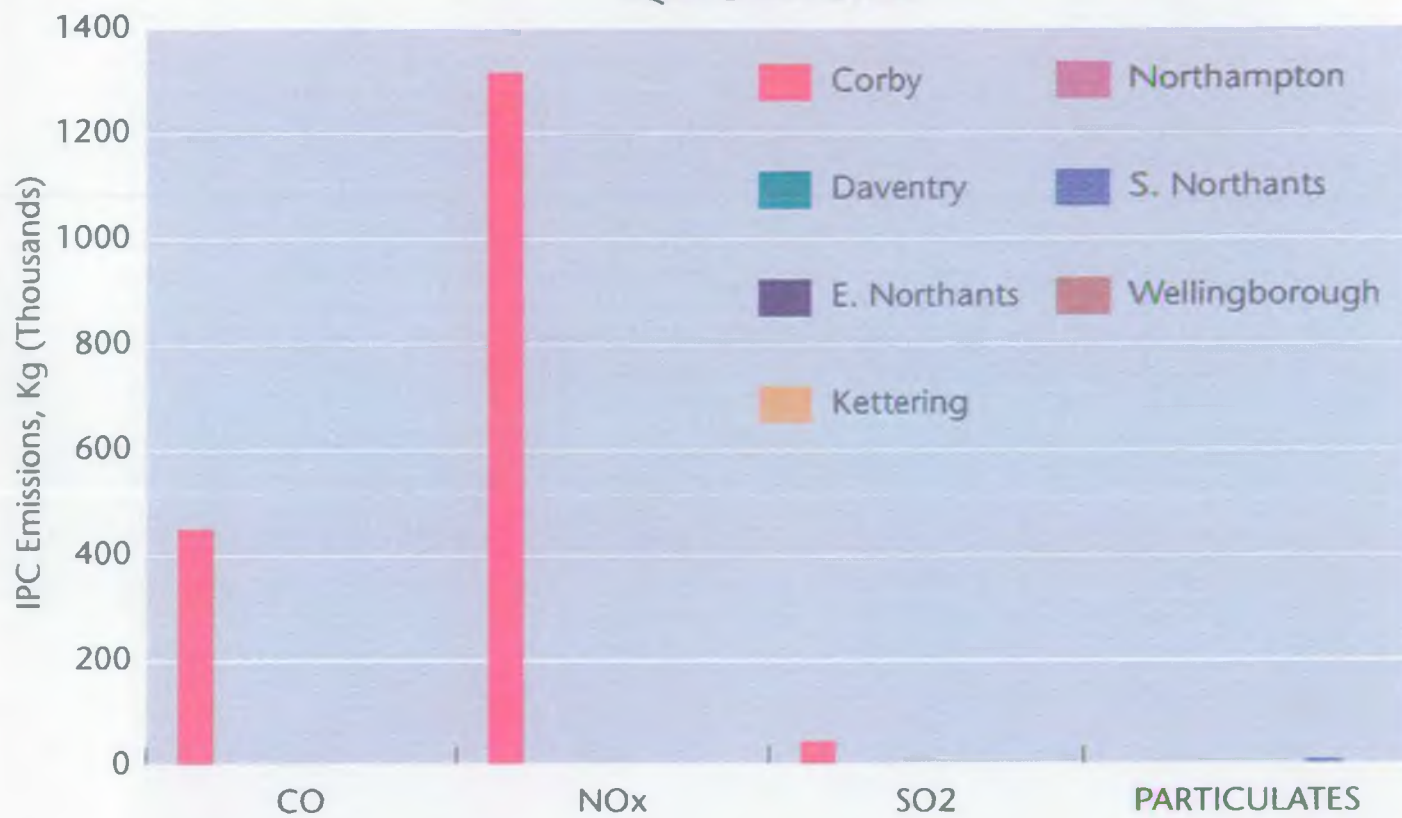




Figure 28 - IPC Emissions to Air, Northants, 1995

AQMS SUBSTANCES



## 4 UNITS AND CONVERSION FACTORS

The following conversion factors have been used and apply at a temperature of 20 °C and pressure of 1013 mb.

Ozone	1 ppb = 2.00 $\mu\text{g m}^{-3}$
Nitrogen Dioxide	1 ppb = 1.91 $\mu\text{g m}^{-3}$
Oxides of Nitrogen	1 ppb = 1.91 $\mu\text{g m}^{-3}$
Carbon Monoxide	1 ppm = 1.16 $\text{mg m}^{-3}$
Sulphur Dioxide	1 ppb = 2.66 $\mu\text{g m}^{-3}$
Benzene	1 ppb = 3.29 $\mu\text{g m}^{-3}$
1,3-butadiene	1 ppb = 2.25 $\mu\text{g m}^{-3}$
1 ppm = 1000 ppb	
1 ppb = 1 part per billion ( $10^9$ )	

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