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# A comparison of national maps of $NO_2$ and $PM_{10}$ concentrations with data from the NETCEN 'Calibration Club'

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# Executive Summary

UK-wide maps of current $NO_2$ and $PM_{10}$ concentrations have been prepared to support the UK Government's development of policies to improve air quality. Maps of both background and roadside ambient concentrations of $NO_2$ and $PM_{10}$ for 1999 have recently been prepared to support the development of the Government's policy to reduce $PM_{10}$ concentrations. These maps are based on emissions inventory information and have been calibrated with reference to automatic ambient air quality monitoring data from the national networks.

Local authorities undertaking review and assessment activities also undertake extensive automatic air quality monitoring. A number of local authorities have chosen to participate in a 'Calibration Club' operated by NETCEN, which provides a service including independent equipment audits, calibration and a data collection and ratification service similar to that used in the national networks. This local authority 'Calibration Club' data therefore provides an excellent independent data set of known quality, which can be used to verify the mapped estimates of ambient concentrations.

Overall, the agreement between the concentrations measured at the Local Authority 'Calibration Club' sites and the modelled values provided in the maps was found to be reasonably good. This verification for the modelled values indicates that they provide a suitable representation of the air pollution climate in the UK for use in policy analysis studies.

# Contents

# 1 Introduction

UK-wide maps of current $NO_2$ and $PM_{10}$ concentrations have been prepared to support the UK Government's development of policies to improve air quality. Maps of both background and roadside ambient concentrations of $NO_2$ and $PM_{10}$ for 1999 have recently been prepared to support the development of the Government's policy to reduce $PM_{10}$ concentrations. Full descriptions of the methods used to calculate these maps are presented by Stedman et al (2001a). The methods used to calculate these maps have been developed by AEA Technology Environment over a number of years and are described in detail in a number of reports and papers (Stedman et al 1997, Stedman, 1998, DETR *et al* 2000, Stedman et al 2001b, Stedman et al 1998a, Stedman et al 1998b, Stedman and Bush 2000). These maps are based on emissions inventory information and have been calibrated with reference to automatic ambient air quality monitoring data from the national networks.

Maps of annual mean background and roadside concentrations of $NO_2$ are shown in Figures A1 and A3 and maps of annual mean $PM_{10}$ concentrations are shown in Figures A2 and A4 in Appendix 1. Estimates of background concentrations have been calculated for 1 x 1 km squares across the whole of the UK and roadside concentrations have been estimated for 7180 built up A-road and motorway road links. Since data from the national networks has been used to calibrate the relationships between local emissions and ambient concentrations, it is not possible to verify the accuracy of the maps by comparison with this data.

Local authorities undertaking review and assessment activities also undertake extensive automatic air quality monitoring. A number of local authorities have chosen to participate in a 'Calibration Club' operated by NETCEN (part of AEA Technology Environment), which provides a service including independent equipment audits and calibration and a data collection and ratification service similar to that used in the national networks. This local authority 'Calibration Club' data therefore provides an excellent independent data set of known quality, which can be used to verify the mapped estimates of ambient concentrations.

The monitoring sites included in this study are listed in Table 1. Local authorities were contacted to confirm site types and grid references and all those contacted agreed to contribute data to this study. All non-roadside sites are considered as background sites, which are typically at least 30 m from the nearest busy road. Sites intermediate between background and roadside locations (between about 10 m and 25 m from a busy road) were excluded from the analysis because the national maps do not provide estimates of concentration in these locations. Roadside sites adjacent to unclassified or B-roads are also excluded because modelled concentrations have only been calculated for A-roads and motorways, for which national statistics on traffic flows are available. Annual mean concentrations were not calculated for sites with less than 25% data capture. The majority of the sites included in this analysis had data capture greater than 70%. Annual means for 1999 were calculated using fully ratified data. Annual means for 2000 were calculated including some data that remained provisional at the time of analysis.

**Table 1. Local Authority monitoring sites included in the comparison with the results of national modelling**

| Site | Local Authority | Site type |
|---|---|---|
| Abingdon | Vale of White Horse District | URBAN BACKGROUND |
| Basingstoke | Basingstoke and Deane Borough | URBAN BACKGROUND |
| Botley | Vale of White Horse Ditrict | ROADSIDE |
| Brentwood | Brentwood Borough | URBAN CENTRE |
| Bury St. Edmunds Roadside | St. Edmundsbury Borough | ROADSIDE |
| Cambridge Gonville Place | Cambridge City | ROADSIDE |
| Derby LA* | Derby City | URBAN BACKGROUND |
| King's Lynn Power Station** | | |
| King's Lynn Southgates Pk | Kings Lynn and West Norfolk Borough | ROADSIDE |
| Liverpool Islington | Liverpool City | ROADSIDE |
| Liverpool Mobile (Derby Road) | Liverpool City | ROADSIDE |
| Liverpool Speke (LA) | Liverpool City | SUBURBAN |
| Liverpool Victoria Street | Liverpool City | ROADSIDE |
| Marcham | Vale of White Horse District | ROADSIDE |
| Newham Cam Road | London Borough of Newham | ROADSIDE |
| Newham Tant Avenue | London Borough of Newham | URBAN BACKGROUND |
| Norwich St. Stephens | Norwich City | ROADSIDE |
| Oldham West Endhouse | Oldham Metropolitan Borough | URBAN BACKGROUND |
| Oxford East | Oxford City | URBAN BACKGROUND |
| Oxford St Ebbes | Oxford City | URBAN BACKGROUND |
| Ribble Valley Chatburn | Ribble Valley Borough | RURAL |
| Ribble Valley Lillands | Ribble Valley Borough | RURAL |
| Rugby | Rugby Borough | URBAN BACKGROUND |
| Salford M60 | Salford City | URBAN BACKGROUND |
| Stockport Cheadle | Stockport Metropolitan Borough | URBAN BACKGROUND |
| Stockport Marple | Stockport Metropolitan Borough | URBAN BACKGROUND |
| Tameside Two Trees School | Tameside Metropolitan Borough | SUBURBAN |
| Trafford | Trafford Metropolitan Borough | URBAN BACKGROUND |
| Wigan | Wigan Metropolitan Borough | URBAN CENTRE |
| Wigan Leigh | Wigan Metropolitan Borough | URBAN BACKGROUND |
| Winnersh | Wokingham District | URBAN BACKGROUND |
| Wokingham Council Offices | Wokingham District | URBAN BACKGROUND |
| York Bootham | York City | URBAN BACKGROUND |
| York Clifton Moor | York City | ROADSIDE |
| York Dunnington | York City | SUBURBAN |
| York Fishergate | York City | ROADSIDE |

* Data peer reviewed but not ratified

** Data provided by Anglian Power Generation Limited.

The objective of this study is to verify the national maps of background and roadside $NO_2$ and $PM_{10}$ concentrations by comparison with local authority automatic monitoring data collected at

sites within the NETCEN 'Calibration Club'. Scatter graphs and summary statistics are presented in the following section.

# 2 Results

Summary statistics for the comparisons between measured and modelled concentrations are listed in Tables 2 and 3. Means of measured and modelled concentrations have been calculated along with the correlation coefficient, $r^2$. Both measured and modelled concentrations for $PM_{10}$ are listed in $\mu gm^{-3}$ TEOM, or equivalent units (directly as measured by the TEOM instruments). Annual mean concentrations measured during both 1999 and 2000 have been compared with the modelled estimates for 1999. Measured concentrations would be expected to be somewhat lower in 2000 than in 1999 due to the continuing reduction in pollutant emissions from road traffic and other sources. The comparisons of annual means for 2000 with modelled values for 1999 are therefore likely to show a small bias. For example, the average ratio of annual mean $NO_x$ concentrations measured at national network sites in 2000 to that measured in 1999 was 0.94.

Ambient $NO_2$ concentrations vary according to the availability of both NO and oxidant, and are derived within the national models from estimates of $NO_x$ (the sum of NO and $NO_2$, by convention expressed as $\mu gm^{-3}$, as $NO_2$) using non-linear functions. It is quite possible to obtain a sensible looking estimate of $NO_2$ from a combination of an inaccurate estimate of $NO_x$ and an inappropriate $NO_x$ to $NO_2$ conversion. It is therefore prudent to compare modelled and measured $NO_x$ concentrations as well as those of $NO_2$. This is straight forward because $NO_x$ maps are routinely calculated within the national models.

**Table 2. Summary statistics for background sites**

| | **Mean of measurements ($\mu gm^{-3}$)** | **Mean of model estimates ($\mu gm^{-3}$)** | **$r^2$** | **Number of sites** |
|---|---|---|---|---|
| **$NO_x$, 1999[a]** | 48.8 | 52.7 | 0.58 | 17 |
| **$NO_2$, 1999** | 27.9 | 32.8 | 0.67 | 17 |
| **$NO_x$, 2000[a]** | 43.7 | 51.8 | 0.38 | 21 |
| **$NO_2$, 2000** | 25.7 | 32.4 | 0.24 | 21 |
| **$PM_{10}$, 1999** | 18.4 | 17.0 | 0.26 | 11 |
| **$PM_{10}$, 2000** | 16.8 | 16.9 | 0.27 | 18 |

[a] $\mu gm^{-3}$, as $NO_2$

**Table 3. Summary statistics for roadside sites**

| | Mean of measurements ($\mu gm^{-3}$) | Mean of model estimates ($\mu gm^{-3}$) | $r^2$ | Number of sites |
|---|---|---|---|---|
| **$NO_x$, 1999[a]** | 104.0 | 117.5 | 0.72 | 7 |
| **$NO_2$, 1999** | 38.8 | 42.3 | 0.67 | 6 |
| **$NO_x$, 2000[a]** | 132.8 | 135.6 | 0.63 | 11 |
| **$NO_2$, 2000** | 42.4 | 45.8 | 0.60 | 10 |
| **$NO_x$, 1999*[a]** | 101.9 | 124.9 | 0.25 | 8 |
| **$NO_2$, 1999**** | 41.1 | 43.6 | 0.02 | 8 |
| **$NO_x$, 2000***[a]** | 134.6 | 136.3 | 0.38 | 13 |
| **$NO_2$, 2000****** | 45.1 | 45.6 | 0.10 | 13 |
| **$PM_{10}$, 1999** | 20.7 | 20.1 | 0.22 | 9 |
| **$PM_{10}$, 2000** | 19.0 | 19.6 | 0.14 | 12 |

* Including York Clifton Moor
** Including York Clifton Moor and Liverpool Islington
*** Including York Clifton Moor and Liverpool Victoria Street
**** Including York Clifton Moor, Liverpool Victoria Street and Liverpool Islington
[a] $\mu gm^{-3}$, as $NO_2$

Figures 1 and 2 show comparisons of measured and modelled annual mean $NO_x$ and $NO_2$ concentrations at background sites in 1999. The agreement between modelled and measured concentrations is good for $NO_x$ and $NO_2$. Both $NO_x$ and $NO_2$ are slightly over-predicted by the model, this is more noticeable for $NO_2$, particularly at lower measured concentrations and may reflect the somewhat precautionary nature of the non-linear $NO_x$ and $NO_2$ relationship at these concentrations.

Figures 3 and 4 are similar plots comparing measured background concentrations in 2000 with the model results for 1999. The model over-prediction is more pronounced on these plots as expected due to the generally lower concentrations measured in 2000 than in 1999, discussed above. The correlation coefficients are also lower, partly due to the inclusion of data for the Winnersh and Wokingham Council Offices sites for which the model significantly over estimates the measured concentrations (measurements were not made in 1999).

Figure 5 and 6 show comparisons of measured and modelled $PM_{10}$ concentrations at background sites. The measured values show a much narrower range of concentrations than for $NO_x$. This reflects the wide range of sources of $PM_{10}$ including secondary and coarse particles, which typically show less spatial variation than primary pollutants, such as $NO_x$ or primary $PM_{10}$ (APEG 1999). In general annual mean concentrations are reasonably well predicted (the mean of measurements in 1999 was 20.7 $\mu gm^{-3}$ and the mean of the modelled estimates is 20.1 $\mu gm^{-3}$). The correlation coefficients for $PM_{10}$ are generally lower than for $NO_x$ and $NO_2$. This reflects both the smaller range in concentrations and the greater uncertainty in the mapping method for this multi-source pollutant.

Figures 7 and 8 show comparisons of measured and modelled annual mean $NO_x$ and $NO_2$ concentrations at roadside sites in 1999. The agreement between modelled and measured concentrations is generally good for both $NO_x$ and $NO_2$. $NO_x$ and $NO_2$ are slightly over-

predicted by the model. Concentrations are significantly over predicted at the York Clifton Moor roadside site. This site is located close to a roundabout (leading to an out of town shopping centre) on a ring road with relatively fast moving traffic. The modelled estimate reflects traffic speeds on the whole of this road link, and does not attempt to represent the slower speeds close to a junction. The modelled $NO_2$ concentration at Liverpool Islington is much lower than the measured value but there is good agreement between the measured and modelled $NO_x$ concentrations at this site. This is because this site is at the roadside of a quiet road (annual average daily traffic approximately 5000) close to the city centre. The non-linear relationship between $NO_2$ and $NO_x$ concentrations within the model is derived from data from monitoring sites on roads that generally have traffic flow of at least 20,000. The oxidation of NO to $NO_2$ is less complete at these locations than at background sites, due to the lack of oxidant close to busy roads. The Liverpool Islington site is an example of a roadside location where the use of a background type $NO_2$ and $NO_x$ relationship would be more appropriate. These two sites are highlighted as open triangles in the figures and the summary statistics listed in the top part of Table 3 do not include data from these sites. Statistics including these sites have also been calculated and are given in the shaded part of Table 3.

Figures 9 and 10 show similar plots comparing measured roadside concentrations in 2000 with the model results for 1999. Data points for York Clifton, Liverpool Islington and Liverpool Victoria Street are highlighted on these plots. The model underestimates both $NO_x$ and $NO_2$ concentrations at Liverpool Victoria Street. We suspect that this is due to inaccuracies in the traffic flow information. The under- and over-estimates of measured concentrations provided by the model at roadside sites illustrates the errors than can be introduced by using generalised models and nationally available statistics on traffic flows and speeds. While the model provides a reasonable representation of measured concentrations at most sites, there are some locations where more accurate estimates would require more detailed modelling incorporating extensive information on local traffic conditions.

Figures 11 and 12 show comparisons of measured and modelled $PM_{10}$ concentrations at roadside sites. The measured values show a much narrower range of concentrations than for roadside $NO_x$. This is due to the wide range of particle sources contributing to measured $PM_{10}$. The magnitude roadside increment of $PM_{10}$ concentrations (the elevation of roadside concentrations compared with surrounding background areas) relative to background levels is much lower than for $NO_x$ and the modelling of background concentrations is also subject to greater uncertainties for $PM_{10}$, as discussed above. The calibration of the relationship between the roadside increment for $PM_{10}$ and road link emissions is therefore subject to greater uncertainties than for $NO_x$. Given these uncertainties, it is encouraging that the estimates of roadside $PM_{10}$ concentrations are generally in the correct range and there is a positive correlation with the measured values.

Figures 13 to 15 show comparisons of measured and modelled concentrations for 1999 at both ‘Calibration Club’ and national network background monitoring sites. The majority of the national network sites are in major urban centres, with a smaller number in suburbs, smaller urban areas or rural locations. Many of the ‘Calibration Club’ sites are in smaller urban areas and therefore provide valuable verification of the applicability of the modelled estimates in these areas.

Figures 16 to 18 show a similar comparison for roadside sites. Once again higher concentrations tend to be measured at the national network sites and the data for ‘Calibration Club’ sites. These

results confirm the general applicability of the modelled concentrations in smaller urban areas and adjacent to less heavily trafficked roads.

# 3 Conclusions

The agreement between modelled and measured concentrations of $NO_x$ and $NO_2$ at background sites is good. As expected, the agreement is not as good for $PM_{10}$, due to the greater uncertainties associated with modelling this multi-source pollutant. The agreement between modelled and measured roadside concentrations is also generally good but estimates at some sites were poor due to local influences on ambient concentrations that are not represented in the model. The national maps of ambient concentrations are used to assess concentrations across the whole of the UK and to investigate the effectiveness of a variety of different policies in reducing concentrations. The national maps are therefore not expected to provide a full description of concentrations at all locations, particularly at the roadside where local traffic conditions can strongly influence concentrations.

The comparison of both national network and 'Calibration Club' data with modelled values for 1999 shows that the relationship between modelled and measured values is similar for both sets of measurements. The measured concentrations were found to be generally lower at the 'Calibrations Club sites. This provides useful verification of the applicability of the maps in these lower concentration areas.

Overall, the agreement between the concentrations measured at the Local Authority 'Calibration Club' sites and the modelled values provided in the maps is reasonably good. This verification for the modelled values indicates that they provide a suitable representation of the air pollution climate in the UK for use in policy analysis studies.

# 4 Acknowledgements

This work was funded by the Department for Environment, Food and Rural Affairs, The National Assembly for Wales, The Scottish Executive and the Department of the Environment in Northern Ireland. Permission to include monitoring data and detailed information on site locations was kindly provided by the Local Authorities listed in Table 1.

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**Figure 1. Comparison of measured NOx concentration at 'NETCEN Calibration Club' sites with the results of national modelling of background concentrations**

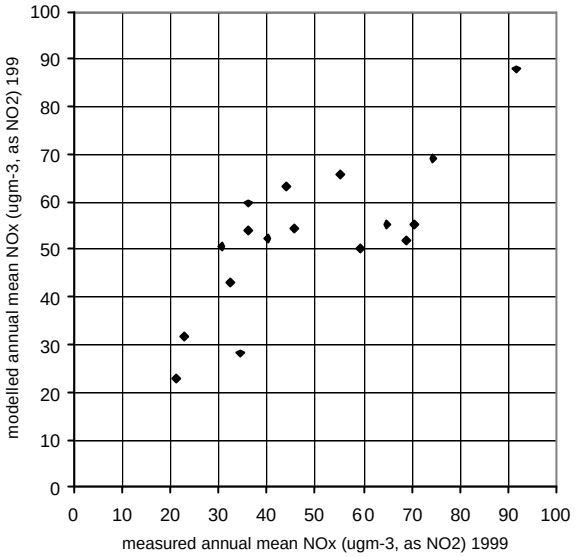
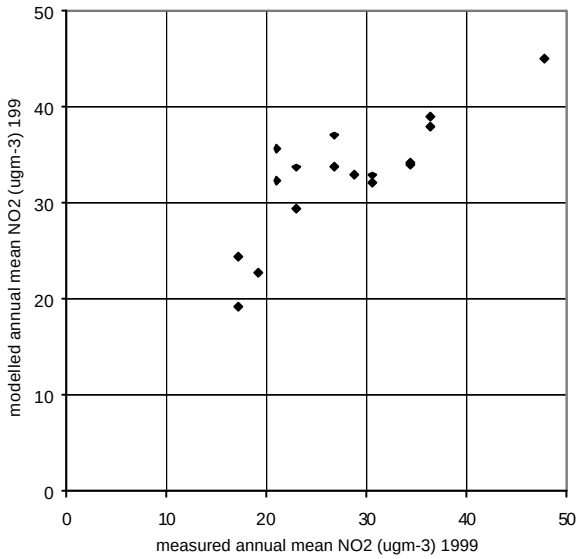



**Figure 2. Comparison of measured NO2 concentration at 'NETCEN Calibration Club' sites with the results of national modelling of background concentrations**



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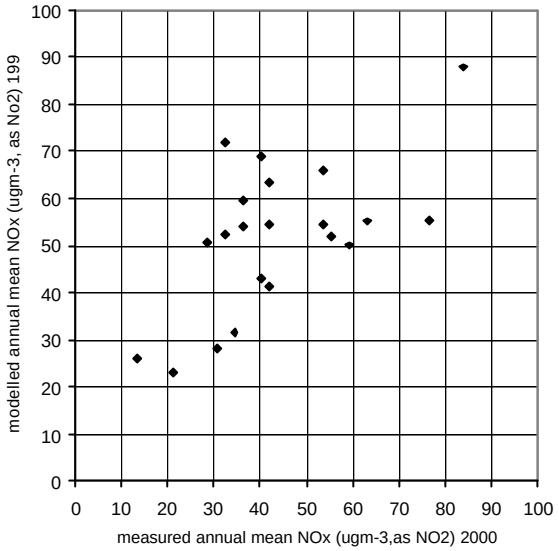



**Figure 4. Comparison of measured NOx concentration at 'NETCEN Calibration Club' sites with the results of national modelling of background concentrations**

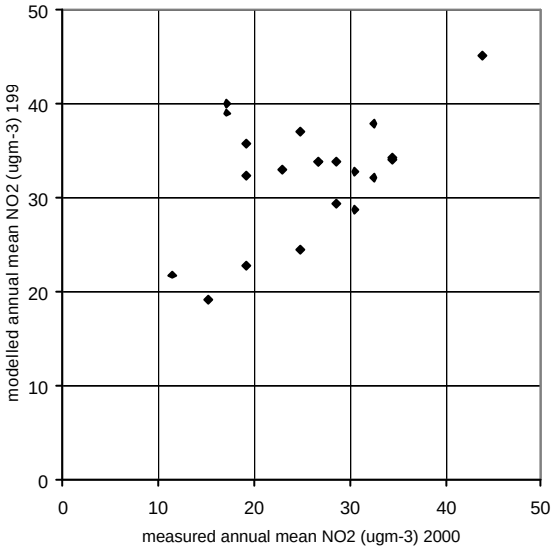


**Figure 5. Comparison of measured PM10 concentration at 'NETCEN Calibration Club' sites with the results of national modelling of background concentrations**

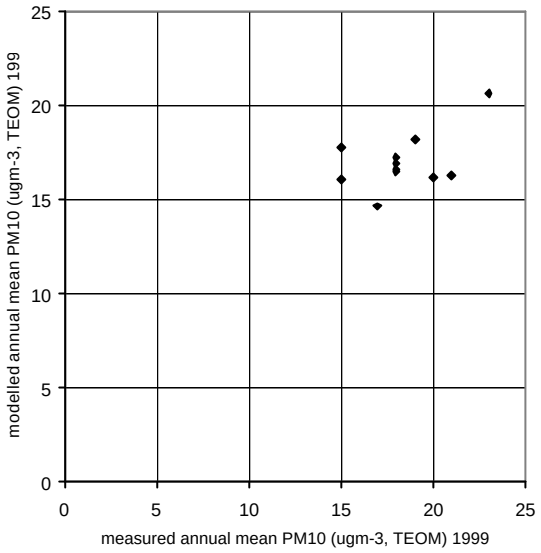



**Figure 6. Comparison of measured PM10 concentration at 'NETCEN Calibration Club' sites with the results of national modelling of background concentrations**

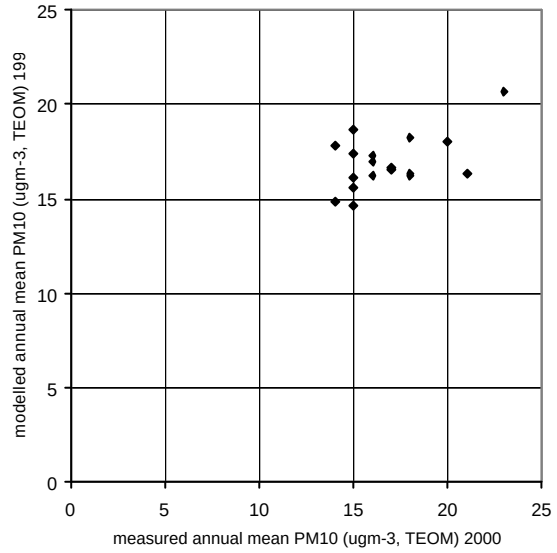


**Figure 7. Comparison of measured NOx concentration at 'NETCEN Calibration Club' sites with the results of national modelling of roadside concentrations**

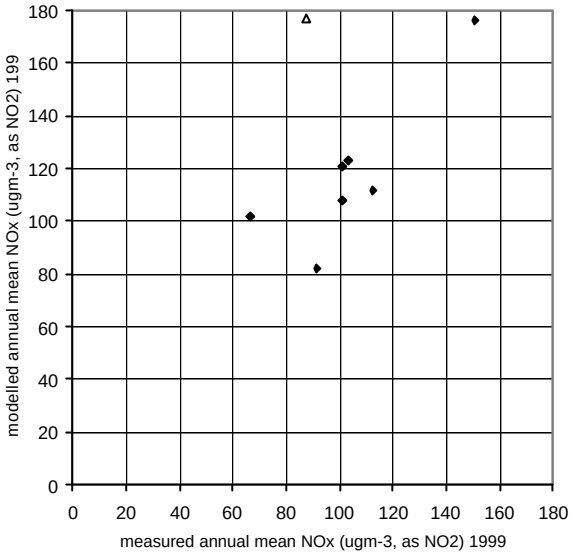



**Figure 8. Comparison of measured NO2 concentration at 'NETCEN Calibration Club' sites with the results of national modelling of roadside concentrations**

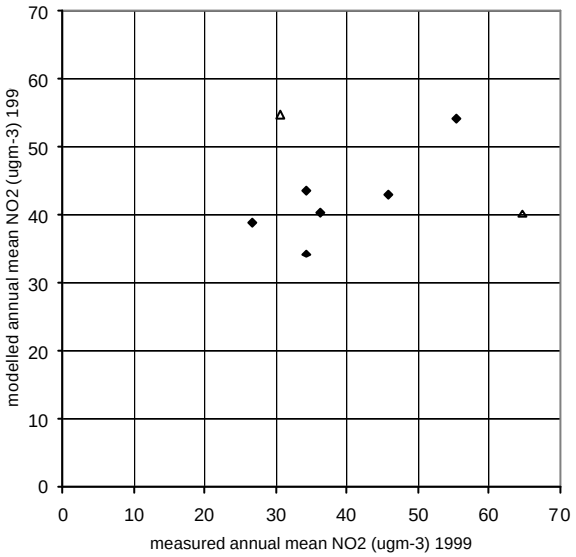


**Figure 9. Comparison of measured NOx concentration at 'NETCEN Calibration Club' sites with the results of national modelling of roadside concentrations**

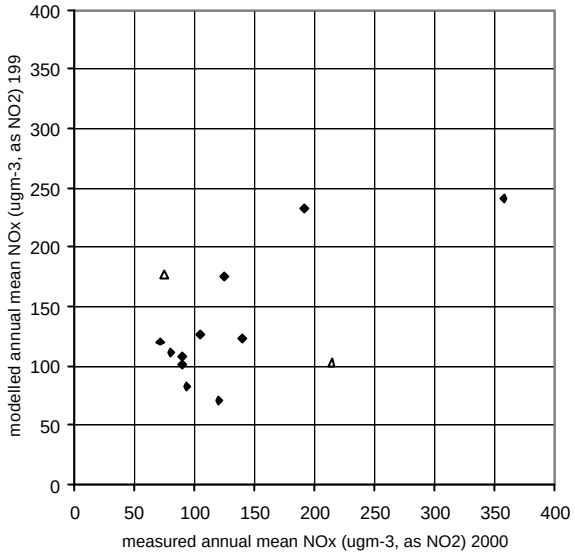



**Figure 10. Comparison of measured NOx concentration at 'NETCEN Calibration Club' sites with the results of national modelling of roadside concentrations**

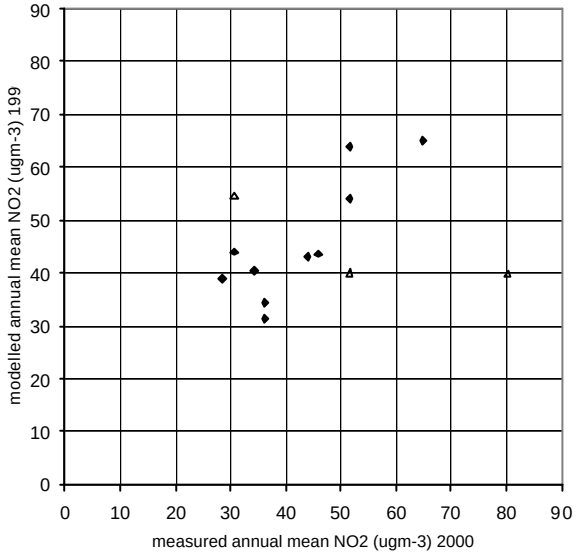


**Figure 11. Comparison of measured PM10 concentration at 'NETCEN Calibration Club' sites with the results of national modelling of roadside concentrations**

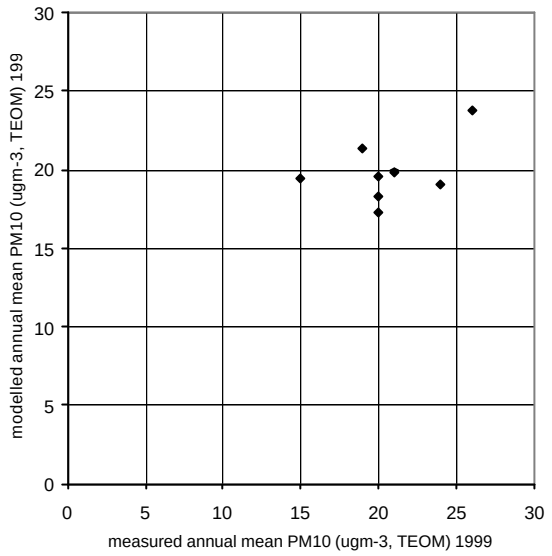



**Figure 12. Comparison of measured PM10 concentration at 'NETCEN Calibration Club' sites with the results of national modelling of roadside concentrations**

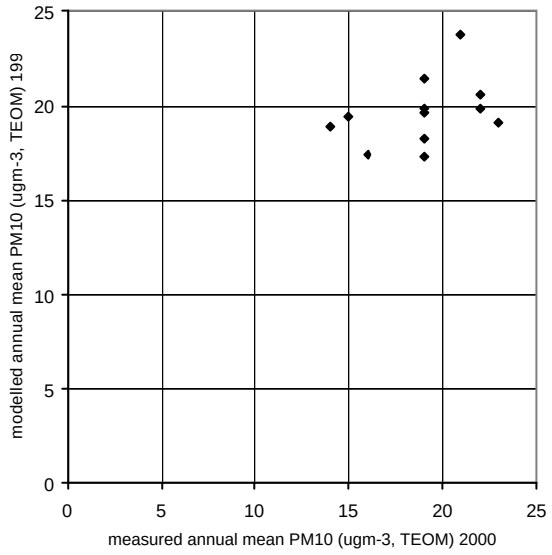


**Figure 13. Comparison of measured NOx concentration at 'NETCEN Calibration Club' and National Network sites with the results of national modelling of background concentrations**

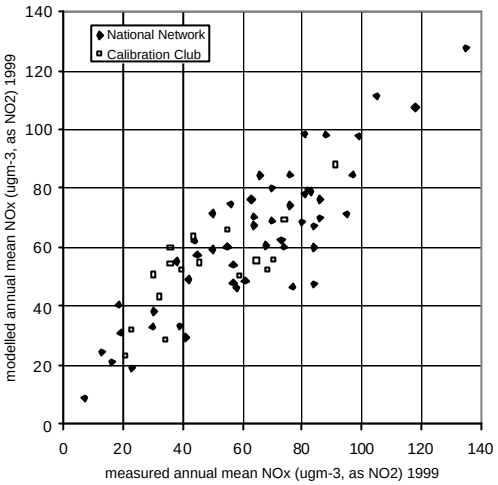



**Figure 14. Comparison of measured NO2 concentration at 'NETCEN Calibration Club' and National Network sites with the results of national modelling of background concentrations**

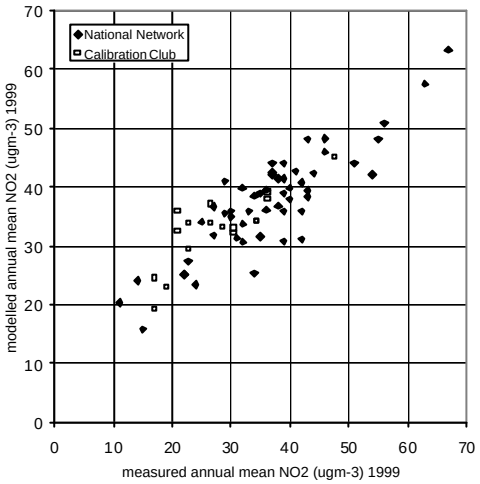



**Figure 15. Comparison of measured PM10 concentration at 'NETCEN Calibration Club' and National Network sites with the results of national modelling of background concentrations**

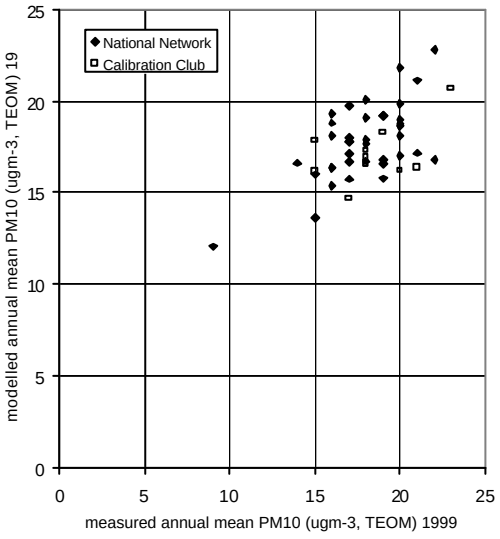
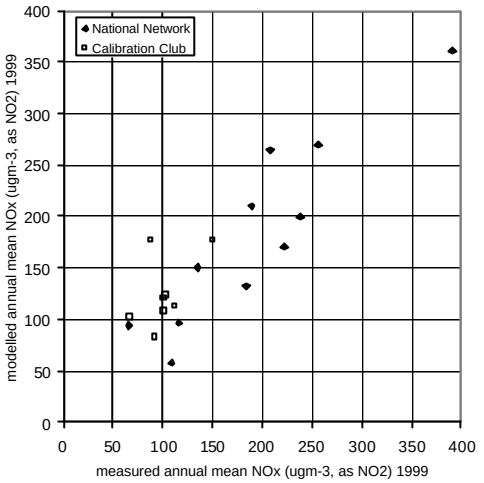


**Figure 16. Comparison of measured NOx concentration at 'NETCEN Calibration Club' and National Network sites with the results of national modelling of roadside concentrations**

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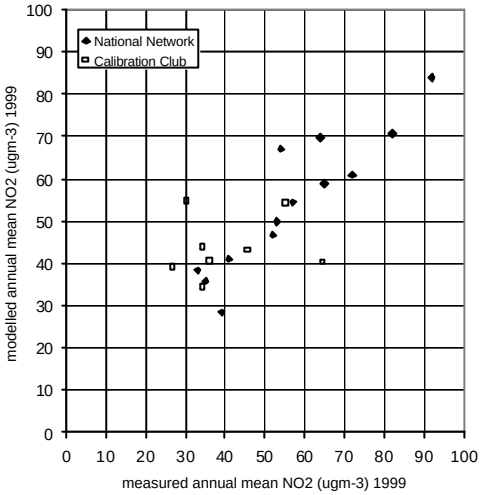
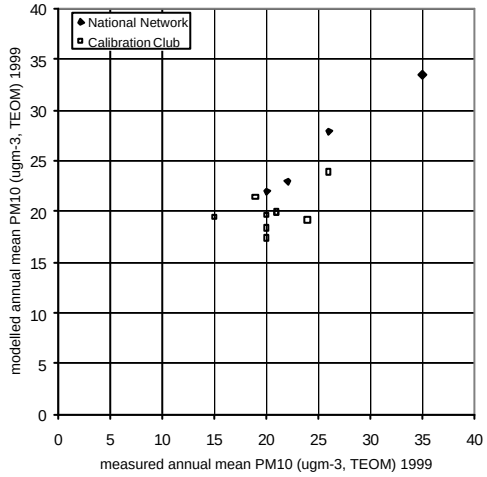



**Figure 18. Comparison of measured PM10 concentration at 'NETCEN Calibration Club' and National Network sites with the results of national modelling of roadside concentrations**



# Appendices

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# Appendix 1
# National Maps for 1999

Figure A1.
Estimated annual mean background nitrogen dioxide concentration, 1999 (ugm-3)
Ref NETCEN 20/09/2000 /naqs3/nox1998naei/UK1NO219991

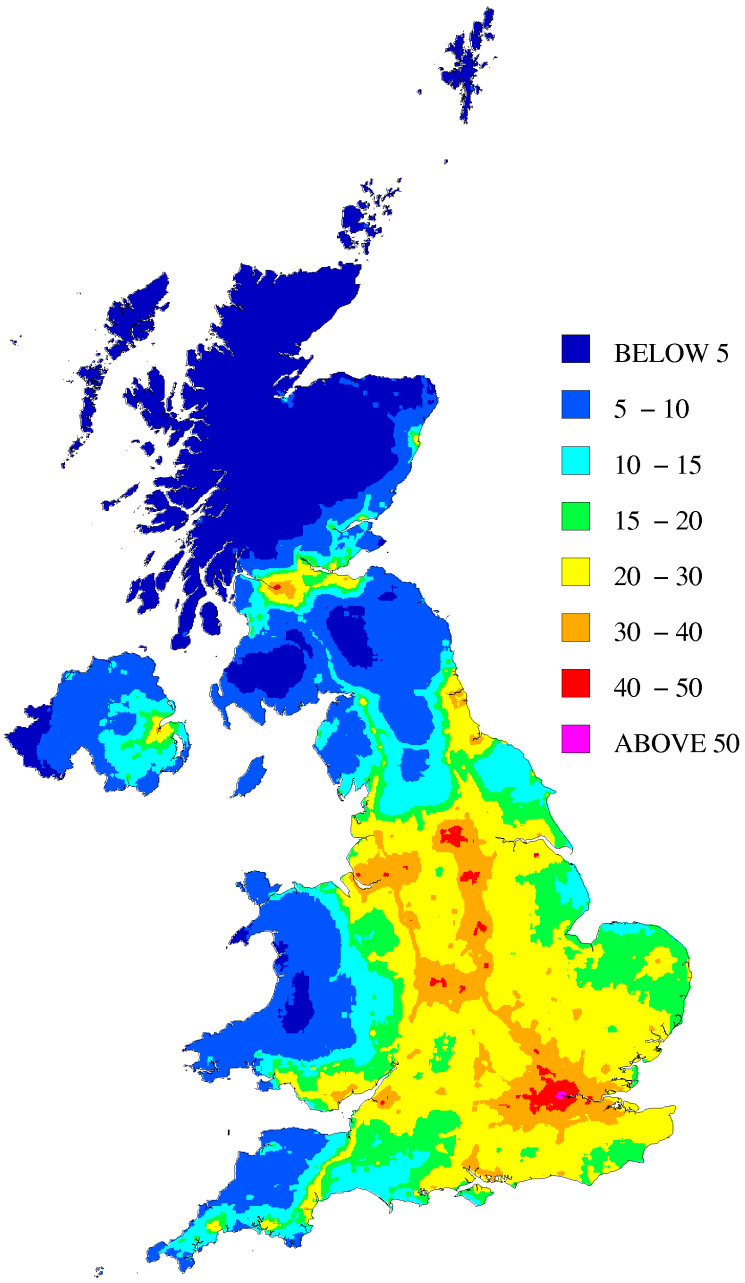

Figure A2.
Estimated annual mean background PM10 concentration, 1999
(ugm-3, gravimetric (TEOM x 1.3)) Ref NETCEN 25/09/2000 JRS UK1PM1019991

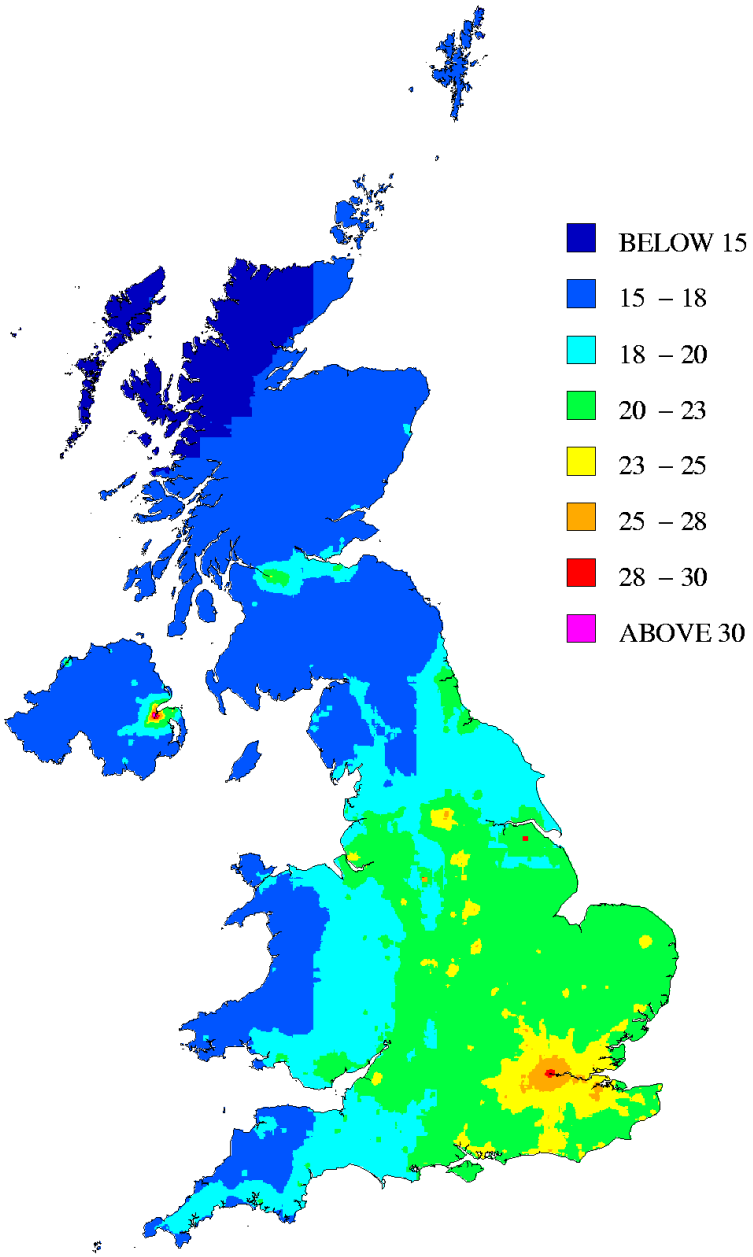

Figure A3.
Major urban roads, estimated annual mean roadside NO2 concentration,
1999 (ugm-3), Ref NETCEN 28/09/2000

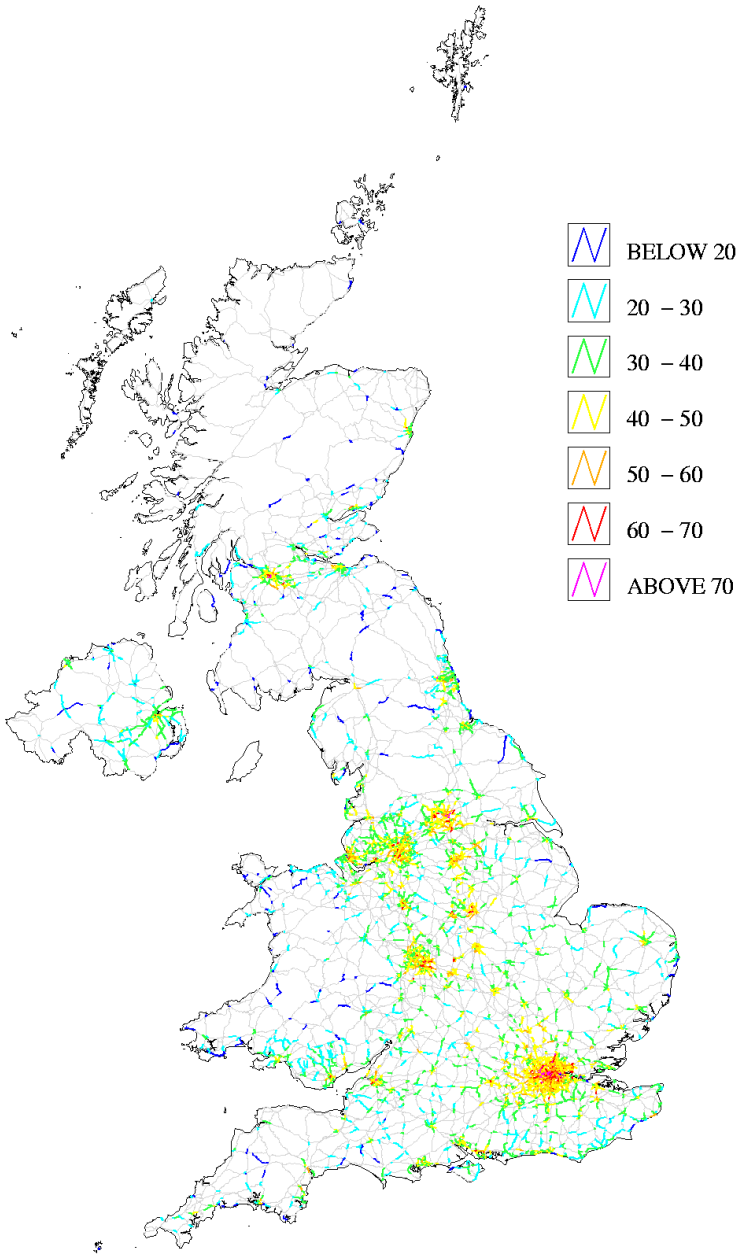

Figure A4.

Major urban roads, estimated annual mean roadside PM10 concentration, 1999 (ugm-3, gravimetric (TEOM x 1.3)) Ref NETCEN 25/09/2000