Dispersion modelling and mapping studies for review and assessment of PM$_{10}$

A report produced for the Department of the Environment, Transport and the Regions

John Abbott and John Stedman

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| **Customer** | Department of the Environment, Transport and the Regions |

| **File reference** | h:\pm10gn7.doc |

| **Report number** | AEAT- 5273 |

| **Report status** | Issue 2 Final |

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Executive Summary

The Department of the Environment, Transport and the Regions (DETR) in conjunction with The Scottish Office and The Welsh Office has issued guidance under the 1995 Environment Act on the approaches that can be adopted to help identify areas within their locality at risk of exceeding the objectives prescribed in the Air Quality Regulations, 1997. The Government has recently published proposals to amend the National Air Quality Strategy: these proposals include an amendment of the air quality objective for PM_{10}. The proposed new objectives for PM_{10} for 31 December 2004 are:

- an annual objective of 40 μg m^{-3};
- a 24 hour objective of 50 μg m^{-3} with a maximum of 35 exceedences (approximately 90 th percentile of 50 μg m^{-3}).

The Government commissioned AEA Technology, Stanger Science and Environment and Air Quality Consultants to prepare informal technical information for local authorities on the approaches that they might take to help identify areas within their locality at risk of exceeding these new objectives for PM_{10}.

This report summarises some research carried out using dispersion models and the development of new maps of estimated background PM_{10} concentrations in support of the development of this technical information for Local Authorities on the review and assessment of PM_{10}. The research covered:

- the development of a simple screening tool for the assessment of emissions of particles from domestic coal burning;
- the development of screening tools for the assessment of industrial stack emissions;
- maps of estimated secondary PM_{10} for 1996 and total PM_{10} for 2004

and is described in this report.

Contents

1 Introduction

1.1 BACKGROUND

The Department of the Environment, Transport and the Regions (DETR) in conjunction with The Scottish Office and The Welsh Office has issued guidance under the 1995 Environment Act on the approaches that can be adopted to help identify areas within their locality at risk of exceeding the objectives prescribed in the Air Quality Regulations, 1997. The Government has recently published proposals to amend the National Air Quality Strategy (NAQS) (DETR *et al*, 1999): these proposals include an amendment of the air quality objective for PM_{10}. The proposed new objectives for PM_{10} (measured by gravimetric or equivalent methods) for 31 December 2004 are:

- an annual objective of 40 μg m^{-3};
- a 24 hour objective of 50 μg m^{-3} with a maximum of 35 exceedences (approximately 90 th percentile of 50 μg m^{-3}).

The Government commissioned AEA Technology, Stanger Science and Environment and Air Quality Consultants to prepare informal technical information for local authorities on the approaches that they might take to help identify areas within their locality at risk of exceeding these new objectives for PM_{10} (Moorcroft *et al*, 1999).

This report summarises some research carried out using dispersion models and the development of new maps of estimated background PM_{10} concentrations in support of the development of this technical information for Local Authorities on the review and assessment of PM_{10}. The research covered:

- the development of a simple screening tool for the assessment of emissions of particles from domestic coal burning;
- the development of screening tools for the assessment of industrial stack emissions;
- maps of estimated secondary PM_{10} for 1996 and total PM_{10} for 2004

and is described in this report.

1.2 GRAVIMETRIC MEASUREMENT DATA

The amended air quality objectives for PM_{10} proposed within the review of the NAQS (DETR *et al*, 1999) are derived from the stage 1 limit values of the European Union 'Daughter Directive'. The reference monitoring method for these limit values is gravimetric but equivalent methods can also be used to implement the Directive. Monitoring of PM_{10} levels in the UK has, to date, been largely based upon the use of TEOM analysers. A principal concern with the TEOM instrument is that the filter is held at an elevated temperature (50°C) in order to minimise errors associated with the evaporation and condensation of water vapour. This can lead to the loss of the more volatile species (some hydrocarbons, nitrates etc.) and has led to the

identification of differences between TEOM and gravimetric measurements at co-located sites. The recently published APEG report (APEG, 1999) concluded that at concentrations around 50 μg/m^3 the TEOM tends to under-read by between 15 and 30% compared with a gravimetric sampler. However, this effect is not constant, and varies depending upon the mass concentration, the distance from a specific source, and the environmental conditions.

There is therefore a potential inconsistency between measurements of PM$_{10}$ concentrations made using a TEOM or equivalent analyser and the proposed objectives - for example, a daily mean concentration of 45 μg/m^3 measured using a TEOM or equivalent analyser could be underestimating the 'gravimetric' or equivalent concentration by 15 μg/m^3 or more. It is therefore necessary to apply a 'correction factor' when assessing TEOM or equivalent measured concentrations against the proposed objectives. For the purpose of the review and assessment procedure Moorcroft *et al*, (1999), a constant factor of 1.3 has been used (consistent with the APEG report), and is applied to TEOM measured concentrations.

Concentrations of PM$_{10}$ throughout both this report and the published informal technical information are therefore referred to as either *(μgm^{-3}, gravimetric)* meaning gravimetric or equivalent measurements or *(μgm^{-3}, TEOM)* meaning TEOM or equivalent measurements.

1.3   RELATIONSHIP BETWEEN 90 TH PERCENTILE 24-HOUR CONCENTRATIONS AND THE ANNUAL MEAN

Analysis of data from urban monitoring stations in the UK national monitoring networks indicates that the following relationship between the 90 th percentile fixed 24-hour PM$_{10}$ average concentration (i.e. 35 exceedences per annum) and the annual mean is reasonably robust:

$$90th\_percentile = 1.79 \times Annual\_mean$$

There is therefore a risk that the proposed 24-hour objective of 50 μgm^{-3}, gravimetric will be exceeded if the annual average PM$_{10}$ concentration is more than 28 μgm^{-3}, gravimetric.

2 Screening tool for domestic coal burning

2.1 INTRODUCTION

The use of solid fuels for domestic heating has largely been replaced by alternative fuels throughout the United Kingdom. However, there are a few areas where there is still significant solid fuel burning, particularly where alternative fuels are not readily available. The adoption of Smoke Control Areas and the resulting use of solid smokeless fuels (SSF) in most urban areas has reduced the potential for exceedences of the proposed new PM_{10} objectives. Nonetheless, there remain a few areas where the possibility of exceedence as the result of coal burning remains. This work was intended to help identify potential areas of exceedence.

2.2 DISPERSION MODELLING

The dispersion model, ADMS Version 2.2, was used to estimate ground level primary PM_{10} concentrations in this study. It is an up-to-date model in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and heat flux at the surface. Concentration distributions are assumed to be Gaussian in stable and neutral conditions, but the vertical distribution is non-Gaussian in convective conditions to take account of the skewed structure of the vertical component of turbulence. It contains a number of complex modules that can allow for the effects of plume rise, complex terrain and buildings. The model is described in a User Manual [CERC, 1995].

The model was used to predict annual average ground level PM_{10} concentrations resulting from 1 g/s primary emissions from a 1 km square area source. Surface roughness was assumed to be 1 m, typical of urban areas. An emission height of 10 m was used to represent emissions at roof level. Average meteorological data for Wyton was used in the analysis. The model was used to predict ground level concentrations on a 31 x 31, 1 km grid. The ground level concentrations resulting from larger area emissions (more than one 1 km grid square) were calculated by addition. Table 1 shows the calculated maximum ground level concentrations for a $1 \text{ g s}^{-1} \text{ km}^{-2}$ emission for a range of source sizes.

Table 1: Ground level concentrations for a $1 \text{ g s}^{-1} \text{ km}^{-2}$ emission

Source size, km x km	Ground level concentration, $\mu g \ m^{-3}$
1 x 1	9.4
2 x 2	11.0
3 x 3	12.6
4 x 4	13.5
5 x 5	14.3

10 x 10	17.0

Exceedences of the proposed 24-hour mean PM_{10} objective (as an equivalent annual mean concentration of 28 μgm^{-3}) are predicted to occur when there are more than N people per square kilometre in coal burning households, where N is calculated from:

$$N = \frac{(28-b)}{c} \frac{3600 \times 24 \times 365}{1000FU}$$

where   b is the annual average background concentration, $\mu g\ m^{-3}$;
          c is the ground level concentration for unit emission, $\mu g\ m^{-3}$, taken from Table 1;
          F is the PM_{10} emission factor for domestic coal burning, 10.4 kg/t (Salway et al, 1996);
          U is the per capita coal consumption in coal burning houses, 1.15 t/a (Abbott, 1996)

Figure 1 shows N plotted against background concentration, b, for a range of area sizes. Figure 2 shows a similar plot for SSF burning areas based on an emission factor of 2.75 kg/t and a per capita consumption of 0.76 t/a.

2.3 REVIEW AND ASSESSMENT PROCEDURE

The risk of exceedence of the proposed objectives in coal-burning areas may be estimated as follows.

1. Determine the area, A, under consideration. Three representative 'area types' have been considered in the assistance, i.e.

    - a small village (approx. 1 km^2 area)

    - a small town (approx. 16 km^2 area)

    - a large town (approx. 100 km^2 area)

2. Users should select the area most appropriate to their situation. Where there is doubt, the larger area should be chosen e.g. a large village would be represented as a 'small town'.

3. Determine the population, p, in the most populated square kilometre.
4. Determine the proportion of land, L, occupied by open space or farmland i.e. excluding gardens and residential roads.
5. Determine the proportion of households, C, burning coal. Assume 10% of houses burning solid fuel in Smoke Control Areas are burning coal.
6. Estimate the maximum density of people in households burning coal:

$$D = \frac{pC}{(1-L)}$$

7. Determine background concentration for 2004 from the national maps. The scoping assessment will not be affected greatly by the element of double-counting introduced resulting from the inclusion of domestic emissions in the background maps.
8. Read off the maximum density of people in coal burning households for the appropriate background emission and area size from Figure 1. If this maximum density exceeds the value of D given above, then the risk of exceeding the objective as a result of domestic coal burning is small.

The risk of exceedence due to SSF use is thought to be less than the risk due to coal use and a graph for SSF has not been included in the report on technical information. The method has also been simplified by considering three sizes of urban areas only.

2.4   EXAMPLES

2.4.1   A small coal burning village.

Assume :

- a population of 3000 in a 1 km square ;
- 60% parkland or open space in the square kilometre;
- 50 % of households burn coal.

then the maximum density of people in households burning coal per square kilometre is :

3000 x 0.5/(1-0.6) =3750.

In this example, assume a background annual average PM_{10} concentration of 21 µg m^{-3} , gravimetric (from, for example, the national maps discussed in section 4). Then Figure 1 shows that for a small area of less than 1 km^2, the method suggests a risk of exceedence if the number of people in coal burning households is greater than 2000. It is concluded that this screening model indicates that a more detailed assessment is necessary.

2.4.2   A town with significant coal burning

Assume :

- an area of approximately 4 km x 4 km ;
- a population in the most densely populated 1 km square of 8000;
- 30% parkland or open space in the most populated square km;
- 20 % of households burn coal.

then the maximum density of people in households burning coal per square kilometre is :

8000 x 0.2/(1-0.3) =2285.

Assume, in this example, also a background annual average PM_{10} concentration of 23 $\mu g\ m^{-3}$, gravimetric. Then Figure 1 shows that for an area of approximately 16 km^2, the method suggests a risk of exceedence if the number of people in coal burning households is greater than 1000. It is concluded that this screening model indicates that a more detailed assessment is necessary.

2.4.3   A city

Assume :

- an area of approximately 10 km x 10 km ;
- a population of 8000 in the most densely populated 1 km square;
- 30% parkland or open space in the most populated square km;
- 4 % of households burning coal.

then the maximum density of people in households burning coal per square kilometre is :

8000 x 0.04/(1-0.3) =460.

Assume, in this example, a background annual average PM_{10} concentration of 22 $\mu g\ m^{-3}$, gravimetric. Then Figure 1 shows that for an area of approximately 100 km^2, the method suggests a risk of exceedence if the number of people in coal burning households is greater than 930. It is concluded that this screening model indicates that a more detailed assessment is not necessary.

3   Industrial stacks

3.1   INTRODUCTION

The relationship between 90 th percentile of fixed 24-hour mean and annual mean PM_{10} concentrations described in section 1.3 is very unlikely to hold for the contribution from industrial stack emissions to ambient PM_{10} concentrations. It is therefore more appropriate in areas with significant industrial stack PM_{10} emissions to calculate estimates of the 90 th percentile of PM_{10} for direct comparison with the proposed 24-hour limit value of 50 μgm^{-3}.

Dispersion models may be used to assess the impact of industrial stack emissions on the 90 th percentile daily average PM_{10} concentrations. The formal process requires both local sequential hourly meteorological data and hourly measurements of background concentrations and involves:

- calculating the contributions from modelled sources to concentrations at receptors for each hour sequentially using meteorological data for each hour throughout a year;

- adding the background concentration on an hour by hour basis throughout the year;
- calculating the daily average total concentration at each receptor;
- ordering the daily averages at each location in order of decreasing concentration,
- and selecting the value corresponding to the appropriate percentile i.e. the 35th largest value.

It is not practical to carry out this procedure for screening purposes and a simpler method is required for Stage 2 of the review and assessment procedure.

A number of numerical experiments were carried out for specific examples using the formal procedure described above. The results were then compared with simpler methods and the most appropriate simple method has been chosen for inclusion in the informal technical information report. The numerical experiments presented here were carried out using TEOM monitoring data. The resulting method for estimating 90 th percentiles is equally applicable to both TEOM or equivalent and gravimetric or equivalent monitoring methods.

3.2   THE DISPERSION MODEL

The dispersion model , ADMS Version 2.2, described in section 2.2, was also used for this part of the study. The study made use of two main modes of operation of the model:

- short term, in which the concentrations at receptors are calculated and reported sequentially for each hour of a meteorological data set, for data sets of up to 99 hours;
- long term, in which the concentrations are calculated sequentially for each hour of a meteorological data set using a data set that covered a complete year but concentrations are reported only as averages and percentile values at each receptor.

A computer script was prepared to facilitate the multiple runs of the model in the short term mode required to cover a complete year's meteorological data. Model runs in long term mode were used solely to identify the locations where average and percentile concentrations would be highest.

3.2.1   Sources modelled

Hypothetical new sources close to the national urban background PM_{10} monitoring stations at Manchester Piccadilly and Liverpool Centre were modelled in order to assess their incremental impact on air quality. The modelled sources had the following characteristics:

Stack height	25, 50, 100 m
Stack diameter	1 m
Discharge velocity	15 m/s
Discharge temperature	150 °C
Primary PM_{10} Emission rate	1 g/s

3.2.2   Meteorological data

Sequential hourly meteorological data for Manchester (Ringway) Airport for 1996 were used throughout the study. The data represented meteorological conditions in terms of wind speed, wind direction, time of day, time of year and cloud cover. The ADMS-2 meteorological pre-processor was used to provide estimates of boundary layer height for each hour throughout the year.

A surface roughness value of 0.5 m was used to represent the terrain, characteristic of open suburbia.

3.2.3 Receptors

The model was initially run in long term mode using a 21 x 21 node grid with grid spacing 100m centred on the source in order to identify the locations of the highest modelled concentrations (annual mean and percentile). The model was then used in short term mode to calculate hourly concentrations at each of these receptors.

3.2.4 Calculation of percentiles

The 99.9 th percentile hourly value was determined from the hourly values by determining the 9th largest hourly value. The 98 th and 90 th percentile daily values were obtained by averaging the hourly values for each day of the year (midnight to midnight) and then selecting the 7 th and 35 th largest daily averages.

The dispersion model ADMS was unable to calculate concentrations for a small number (~200) hours as a result of inadequate meteorological data or calm conditions. These hours were excluded from the analysis.

3.2.5 Results

The maximum modelled ground level concentrations are shown in Table 2. Table 2 also shows comparable values calculated using the Environment Agency's (EA) Guidance for estimating the air quality impact of stationary sources and HMIP's Technical Guidance Note (Dispersion) D1.

Table 2: Modelled maximum ground level concentrations

Statistic	Model	Primary PM_{10} Concentration, $\mu g\ m^{-3}$		
		25m stack	50m stack	100m stack
Annual average	ADMS	1.11	0.317	0.074
90th percentile fixed 24 hour	ADMS	4	1.15	0.271
98th percentile fixed 24 hour	ADMS	6.62	1.7	0.5
99.9th percentile hourly	ADMS	16	6.93	2.75
Annual average	EA Guidance	1.2	0.27	0.06
99.9th percentile hourly	EA Guidance	18.5	8	3.8

| 98th percentile hourly | D1 | 7.14 | 1.75 | 0.43 |
| Annual average | D1 | 1.25 | 0.30 | 0.075 |

Table 3 shows the ratio of the 90 th percentile daily average concentration to other statistics calculated from Table 2. It is therefore recommended that an estimate of the 90 th percentile of daily average stack contributions can be derived by multiplying the modelled annual mean stack contribution by 4.0 or the 98 th percentile of hourly values by 0.66.

Table 3 : Ratio of 90th percentile daily average concentration to various surrogates

Statistic	Model	Ratio		
		25m	50m	100m
Annual average	ADMS	3.6	3.6	3.7
Annual average	EA Guidance	3.3	4.3	4.5
99.9th percentile hourly	EA Guidance	0.226	0.145	0.071
98th percentile hourly	D1	0.56	0.66	0.63

3.3 THE ADDITION OF BACKGROUND CONCENTRATIONS

National air quality monitoring data for the United Kingdom are archived by AEA Technology on behalf of the Department for the Environment, Transport and the Regions, The Welsh Office, The Scottish Office and the Department of the Environment, Northern Ireland. The following PM_{10} concentration measurements for 1996 for the following sites were used in the analysis:

> Manchester Piccadilly
> Liverpool Centre

The hourly measurements of urban background PM_{10} concentrations (in TEOM units) were added to the modelled primary PM_{10} concentrations from the industrial stack source using an Excel 5.0 spreadsheet.

There are a small number of hours missing from the air quality monitoring data set. The ambient concentrations were set to zero for hours with missing data. (In a more detailed analysis, these missing values could be interpolated from adjacent hours or estimated from measurements at nearby monitoring sites.)

The relative magnitude of the background concentrations and the stack contributions depends on the rate of emission of pollutants. The methods are required to be useful across the range of emissions. The calculation methods have therefore been applied for emission rates such that the maximum 90th percentile daily stack concentration is equal to the 90 th percentile daily background concentration. The results were normalised by dividing by the 90th percentile daily background concentration. The results are shown in Table 4.

Table 4: Normalised maximum total 90 th percentile fixed daily PM_{10} concentrations

	Normalised 90 th percentile daily total concentration	
	Liverpool Centre	Manchester Piccadilly
25 m	1.65	1.60
50 m	1.62	1.58
100 m	1.59	1.57

Table 4 shows that the normalised 90 th percentile total concentration is typically 1.6 times the 90th percentile background concentration.

3.4 THE REVIEW AND ASSESSMENT PROCEDURE

It is recommended that the 90 th percentile concentration including background and stack contributions is calculated as follows:

1. Determine the 90 th percentile fixed daily background PM_{10} concentration:
   - from local monitoring data (from a site not directly influenced by the stack emissions);
   - or from background maps of annual average concentrations by multiplying by 1.79 (see section 1.3).
2. Determine the 90 th percentile fixed daily primary PM_{10} stack contribution:
   - from EA Guidance by multiplying the annual average by a factor of 4;
   - or using D1 and multiplying the D1 value by a factor of 0.66.[1]
3. Determine which is the larger of the above.
4. Calculate the 90 th percentile of fixed daily means for the total PM_{10} concentration as the sum of the larger value and 0.6 times the smaller value.

Figure 3 shows the maximum 90th percentile stack contribution for a range of annual average background concentrations.

3.5 EXAMPLE

In this example, assume that the annual average background in the vicinity of a stack is 21 μg m^{-3}, gravimetric (from the national maps). The 90 th percentile value is then estimated as 1.79 x 21 =38 μg m^{-3}, gravimetric.

The annual average stack contribution is estimated to be 10 μg m^{-3}, gravimetric from EA Stationary source guidance. The 90 th percentile is then estimated as 4 x 10=40 μg m^{-3}, gravimetric.

The background values is the larger so that the total 90th percentile is estimated to be 40+0.6 x 38=63 μg m^{-3} gravimetric, which is in excess of the proposed 24-hour limit value of 50 μgm^{-3}. It is concluded that this screening method indicates that a more detailed assessment is necessary.

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[1] EA Guidance is preferred except for stacks less than 20 m high or where there are buildings taller than 40 % of the stack height within 5 stack heights .

4   Mapping studies

4.1   INTRODUCTION

The mapping of background PM_{10} concentrations across the UK is a complex task because of the variation in composition and source apportionment of particles between different locations. The PM_{10} mapping methods used within the DETR research programme have developed considerably over recent years as the understanding of the source apportionment of PM_{10} has improved (Stedman *et al*, 1997, Stedman, 1998). A map of estimated annual mean PM_{10} for 1996 has been published by Stedman (1998) along with maps of the other National Air Quality Strategy (NAQS) pollutants. These mapping techniques were later extended by incorporating the findings of the recently published report of the Airborne Particles Expert Group (APEG, 1999) to calculate daily maps of PM_{10} within the review of the NAQS (Stedman *et al*, 1998, DETR *et al*, 1999).

While a number of uncertainties remain within the mapping methods that have been developed, it is clear that the most important requirement for the calculation of maps of estimated pollutant concentrations is that they should be fit for purpose. The maps of estimated PM_{10} concentration that have been calculated here for use within the review and assessment process have been developed within the framework of the drafting of the technical information. A priority in the choice of mapping methods is that the maps are fully integrated into the review and assessment process and have been calculated in a manner consistent with the recommended procedures for review and assessment. This enables calculations to be carried out consistently throughout the procedure, so that, for example, the treatment of coarse particle concentrations will be identical whether background concentrations are derived from the maps or from ambient monitoring data.

Two maps are required for the review and assessment procedure for the proposed PM_{10} objectives and these maps will be made available within the National Air Quality Information Archive on the World Wide Web:

www.aeat.co.uk/netcen/airqual/

These maps are

- background annual mean secondary PM_{10} in 1996
- background annual mean total PM_{10} in 2004.

Both maps show background PM_{10} concentrations as measured by a gravimetric or equivalent method.

4.2   SOURCE APPORTIONMENT OF PM$_{10}$

The source apportionment of PM$_{10}$ has recently been reviewed by APEG (1999) and the sources that are thought to make significant contribution to ambient background concentrations in the UK are listed in Table 5.

Table 5: Source apportionment of background PM$_{10}$

Size	Main Categories	Main Source Types
Fine (< 2.5 μm)	Primary	local vehicle exhaust
		local combustion sources
		regional vehicle exhaust
		regional combustion sources
	Secondary	regional sulphates and nitrates
Coarse (2.5 - 10 μm)	Natural	regional resuspended soil and dust, sea salt
	Man made	resuspended dusts, mechanically derived particles

A map of estimated PM$_{10}$ concentration therefore need to take each of these sources into account.

4.3   A MAP OF SECONDARY PM$_{10}$ FOR 1996

Figure 4 is a map of estimated secondary PM$_{10}$ concentrations for 1996. This map has been calculated from the map presented as Figure 4.8 in the APEG report by multiplying by 1.3. The APEG map was derived from rural sulphate measurements using the methods recommended by QUARG (1996). The factor of 1.3 has been applied because the receptor modelling relationships used by APEG were based on TEOM monitoring data:

secondary PM$_{10}$ (gravimetric units) = 1.3 x secondary PM$_{10}$ (TEOM units)

1996 was chosen as the base year for the review and assessment procedure due to the unusual 'worst case' secondary particle episodes experienced in the early part of the year (APEG 1999).

4.4   A MAP OF TOTAL PM$_{10}$ FOR 2004

4.4.1   Introduction

The 2004 map has been calculated in two stages:
- a map of total PM$_{10}$ for 1996 has been estimated
- appropriate emission reduction factors were applied to the individual components of the map

4.4.2   1996

This map is shown in Figure 5a and has been derived using the following equation:

estimated PM$_{10}$ (gravimetric units) = 1.3 x secondary PM$_{10}$ (TEOM units)

$$+ \ 1.3 \ x \ k_1 \ x \ local \ primary \ emissions \ (kTonnes \ per \ 25 \ km^2 \ per \ year)$$
$$+ 1.3 \ x \ coarse(TEOM \ units)$$

The treatment of secondary PM_{10} is the same as used to derive Figure 4. The primary component has been calculated from local primary emissions from area sources (but excluding all industrial sources) estimated within the National Atmospheric Emissions Inventory. The coefficient, k_1, has been derived by regression analysis of TEOM monitoring data from the DETR national air quality monitoring networks. The value of this coefficient has been allowed to vary as follows, in order to achieve best fit to the monitoring data and take into account any systematic errors in the emissions estimates:

- Northern Ireland: 0.024
- London: 0.032
- Elsewhere: 0.038

These values can be compared with a similar coefficient for the local contribution to NO_x concentrations (for which the source apportionment and emissions are well understood) of 0.033 in consistent units (Stedman, 1998).

The value of the coarse particle concentration has been set to 8 μgm^{-3} (TEOM units) or 10.5 μgm^{-3} (gravimetric units). This is the typical value found for the coarse particle concentration derived as the residual in the receptor modelling of TEOM data undertaken by APEG (1999) and Stedman *et al* (1998).

4.4.3 2004

The following emissions reduction factors (derived from APEG, 1999) were applied in order to project to 1996 map forward to the 2004 map shown in Figure 5b:

- primary 2004   = primary 1996 x 0.651 (GB)
- primary 2004   = primary 1996 x 0.767 (Northern Ireland)
- secondary 2004   = secondary 1996 x 0.829
- coarse 2004   = coarse 1996

The primary emission reduction factors were derived from forecasts of road traffic exhaust emissions; which are assumed to contribute 75% of total primary combustion emissions in GB and 50% in Northern Ireland; non road traffic exhaust primary emissions are assumed to remain at 1996 levels. The secondary emission reduction factors were derived from secondary particle modelling carried out by EMEP.

This map (Figure 5b) is the one recommended for use within the review and assessment procedure.

4.5   AN ALTERNATIVE MAP OF TOTAL PM$_{10}$ FOR 2004

The map presented in Figure 5b was chosen for inclusion in the review and assessment procedure because the simplifying assumptions incorporated in its calculation enable the review and assessment calculations to be reasonably straight forward.

The treatment of both primary and coarse particle concentrations have, however, been considerably simplified in comparison to the source apportionment findings of APEG. Figures 5c and 5d shown alternative maps of total PM$_{10}$ concentrations for both 1996 and 2004 based on the following more complete breakdown, in which these components have been split into local and regional contributions :

estimated PM$_{10}$ (gravimetric units) = 1.3 x secondary PM$_{10}$ (TEOM units)
+ 1.3 x k$_2$ x local primary emissions (kTonnes per 25 km^2 per year)
+ 1.3 x regional primary (TEOM units)
+ 1.3 x regional coarse(TEOM units)
+ 1.3 x local coarse (TEOM units)

where

regional primary has been estimated from rural NO$_2$ measurements by multiplying by a factor of 0.15. This gives a value that varies from about 2 μgm^{-3} (TEOM units) in the south east to virtually zero in north west Scotland. This is reasonably consistent with both the modelled estimates of long range transported PM$_{10}$ concentrations of 1.9 μgm^{-3} in London and 1.0 μgm^{-3} and long range transported black smoke concentration of about 1.5 μgm^{-3} in East Anglia cited by APEG (1999).

regional coarse has been assumed to be 6 μgm^{-3} across the whole of the country.

local coarse has been estimated by multiplying estimates of construction derived PM$_{10}$ emission from the NAEI across an area of 25 km^2 by 0.20. This factor has been chosen to give an additional urban contribution to coarse particle concentrations of about 2 μgm^{-3} (TEOM units) in central London and zero in rural areas. It is recognised that the local contribution to coarse particle concentrations is due to a range of urban activities including resuspended dusts due to traffic and construction activity, and construction emissions have been used as an indicator of these activities. This indicator was chosen to be consistent with the limited information from measurements of the concentration of coarse particles at sites with co-located PM$_{10}$ and PM$_{2.5}$ monitors (APEG, 1999), which indicated urban levels of about 8 μgm^{-3} in London and Birmingham but only about 5 μgm^{-3} at the rural Harwell site.

The values of the coefficient *k$_2$* are slightly lower than the *k$_1$* values used in Figures 5a and 5b because the regional primary component is treated explicitly, rather than rolled into the local primary:

- Northern Ireland: 0.020
- London: 0.028
- Elsewhere: 0.032

The regional primary concentration has been treated the same as the local primary concentration and the local coarse concentration has been treated the same as the regional coarse concentration in projecting the 1996 map (Figure 5c) forward to 2004 (Figure 5d).

This alternative map has slightly higher estimated total PM_{10} concentrations in 2004 in some urban areas (up to about 2 μgm^{-3} in central London) and lower concentrations in rural areas (by up to about 3 μgm^{-3}). While this map provides a more realistic picture of the likely variation in background annual mean PM_{10} in 2004, it is not compatible with the rest of the review and assessment procedure unless the method is made considerably more complicated. The procedure in the technical information report (Moorcroft *et al*, 1999) has the advantage that the local primary contribution to current PM_{10} can be calculated by subtracting the mapped secondary contribution and a constant concentration of coarse particles from a measured or mapped value. This simplicity would be lost with the more complex map. This underlines that it is possible to calculate several different maps of the same statistic and the importance of ensuring that each map is 'fit for purpose'.

5   References

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Figure1: Maximum number of people in coal burning households per square km and estimated annual mean background PM$_{10}$ concentrations
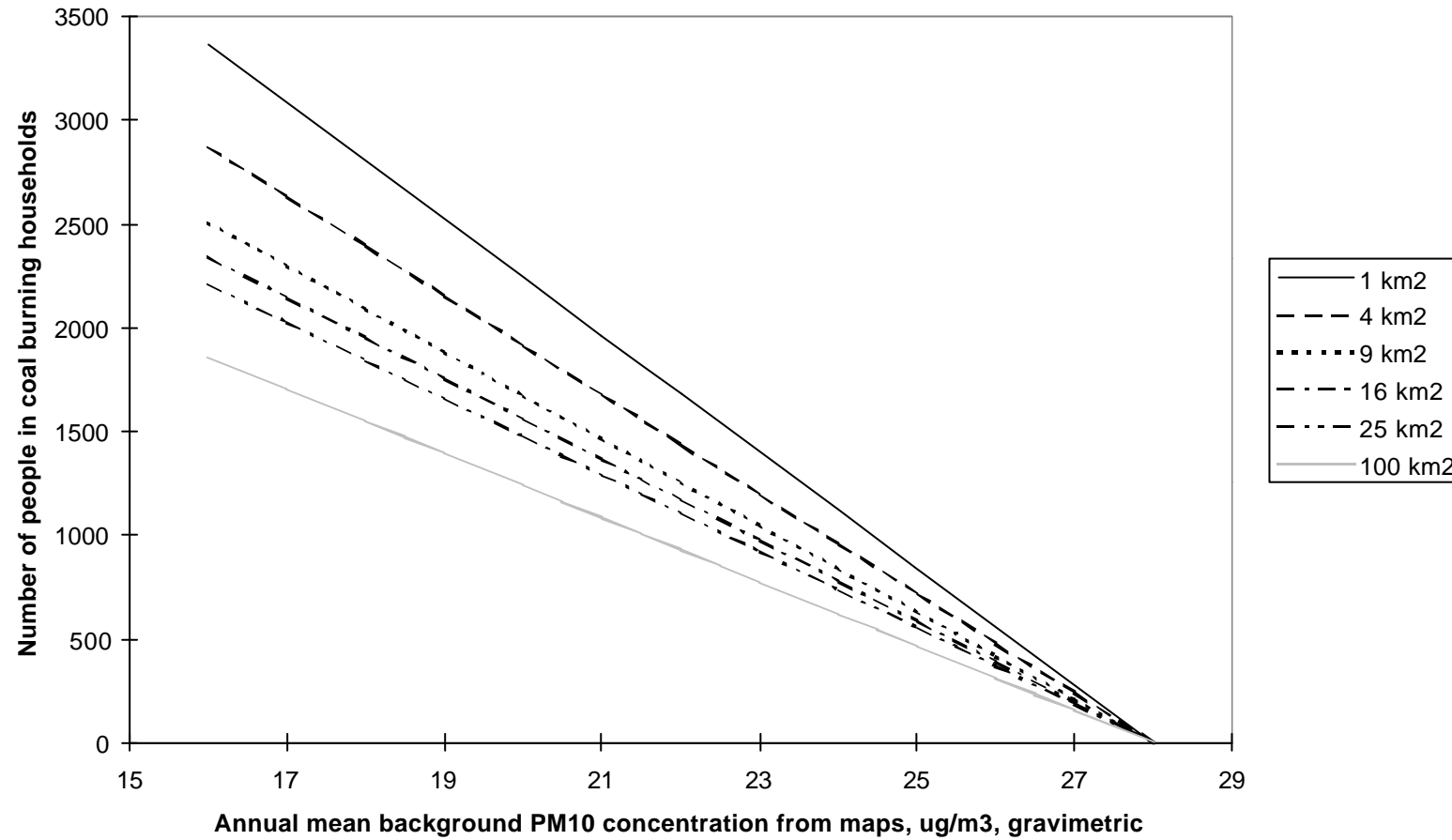
Figure 2: Maximum number of people in households burning Solid Smokeless Fuel per square km and estimated annual mean background concentrations
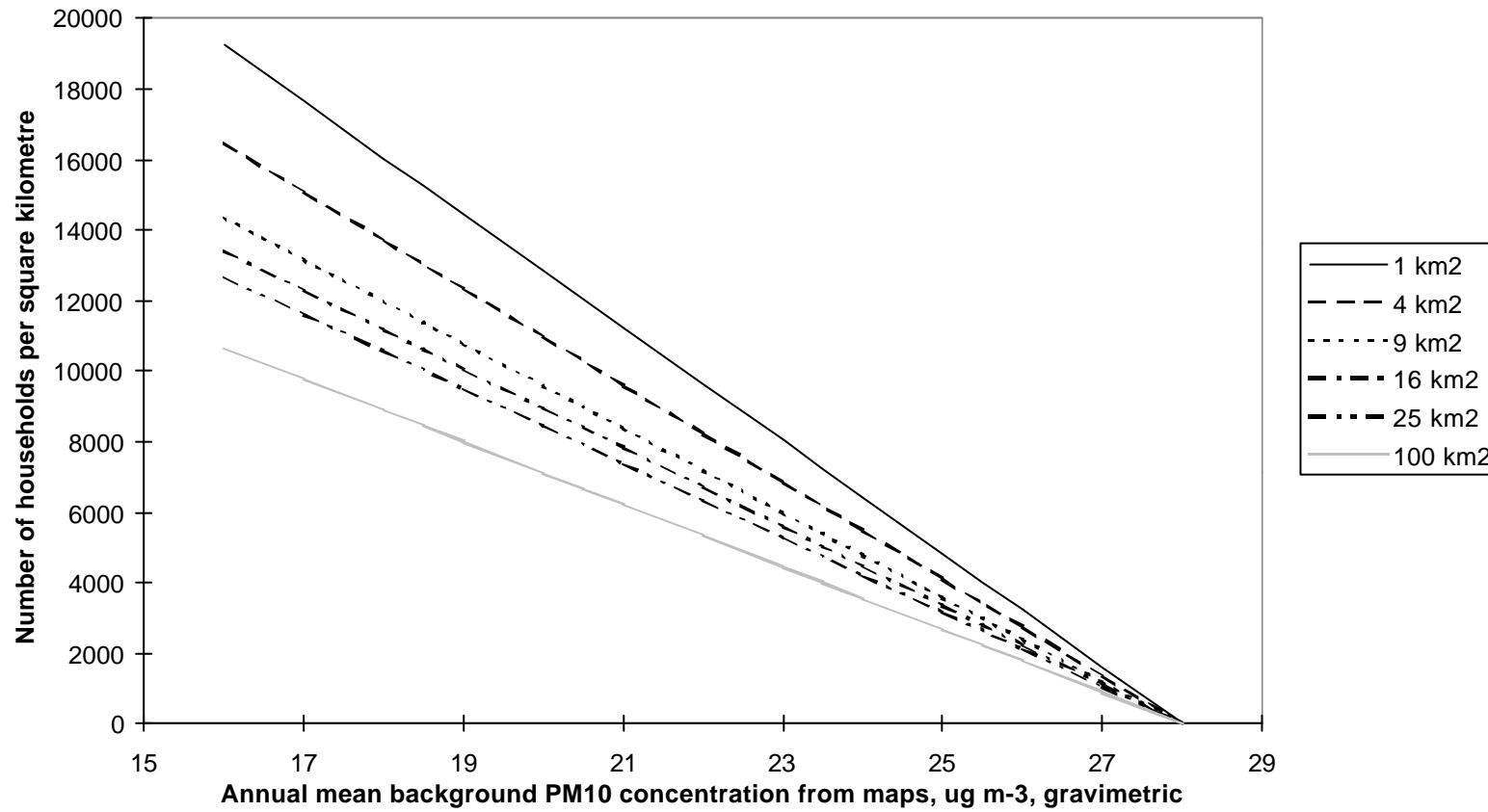
Figure 3: Maximum 90 th percentile stack contribution leading to risk of exceedence of proposed PM$_{10}$ objective for a range of annual mean background concentrations
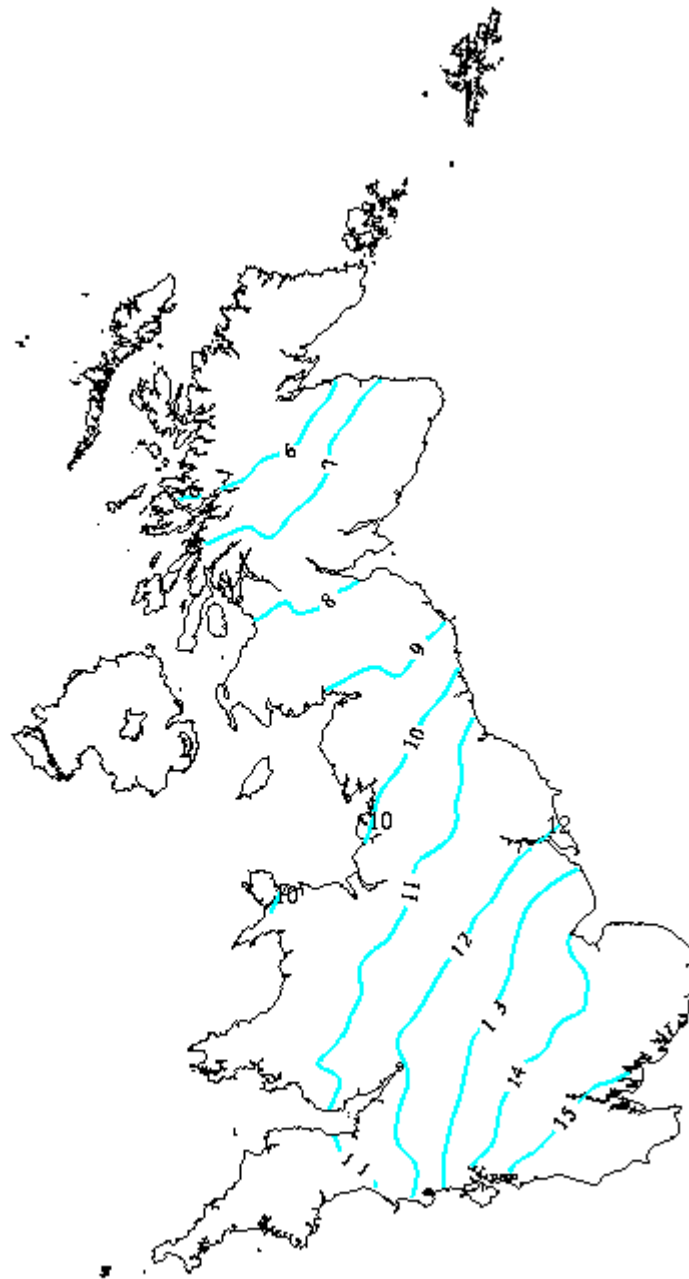

Annual mean background PM10, ug/m3, gravimetric
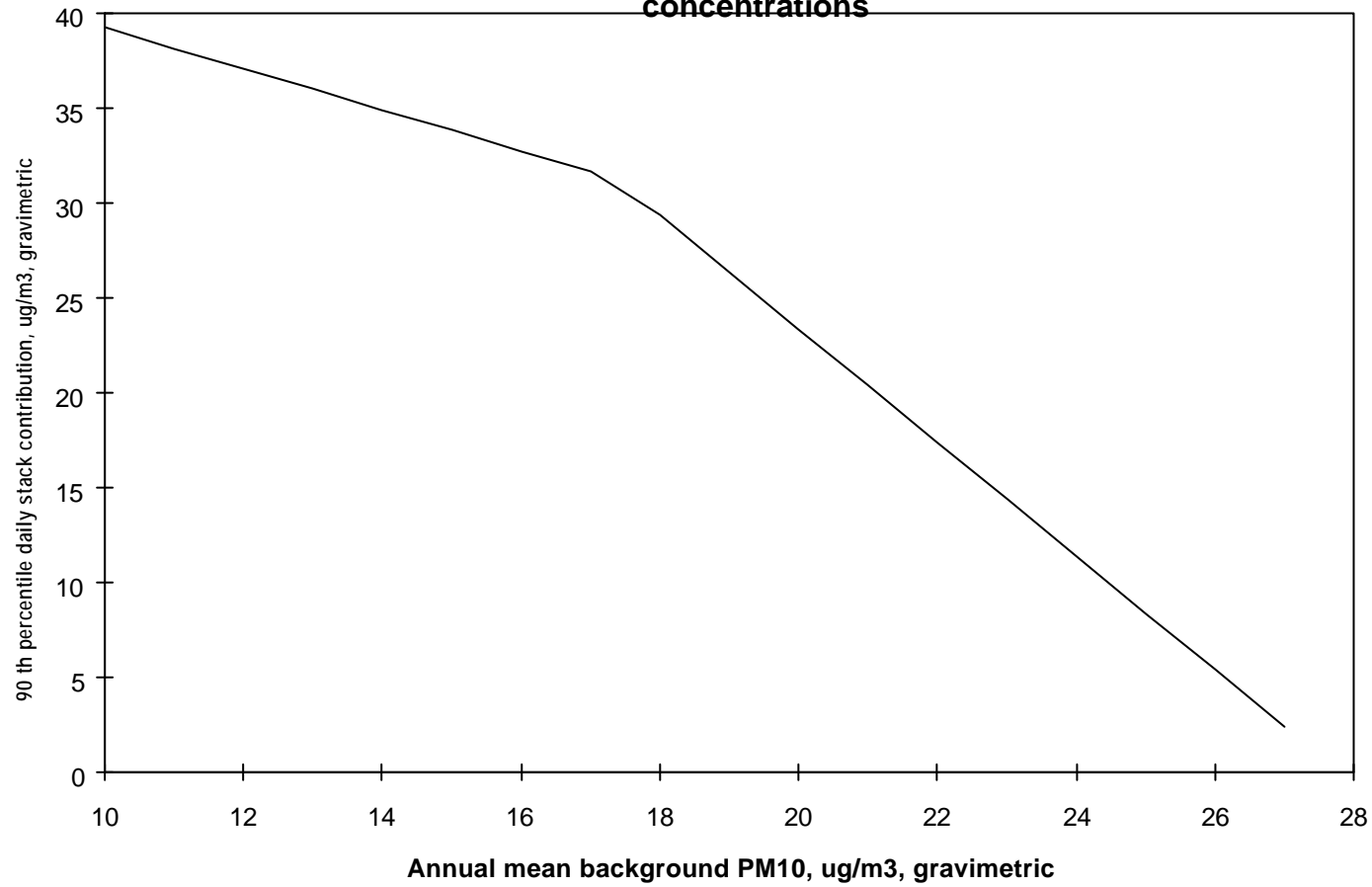
Figure 4. Estimated annual mean secondary PM10 concentration, 1996 (ugm-3)
Ref NETCEN 16/02/99 JRS UK5KM_2PM96G (gravimetric units)
(Values in NI range 7 – 8 ugm-3)

a) 1996
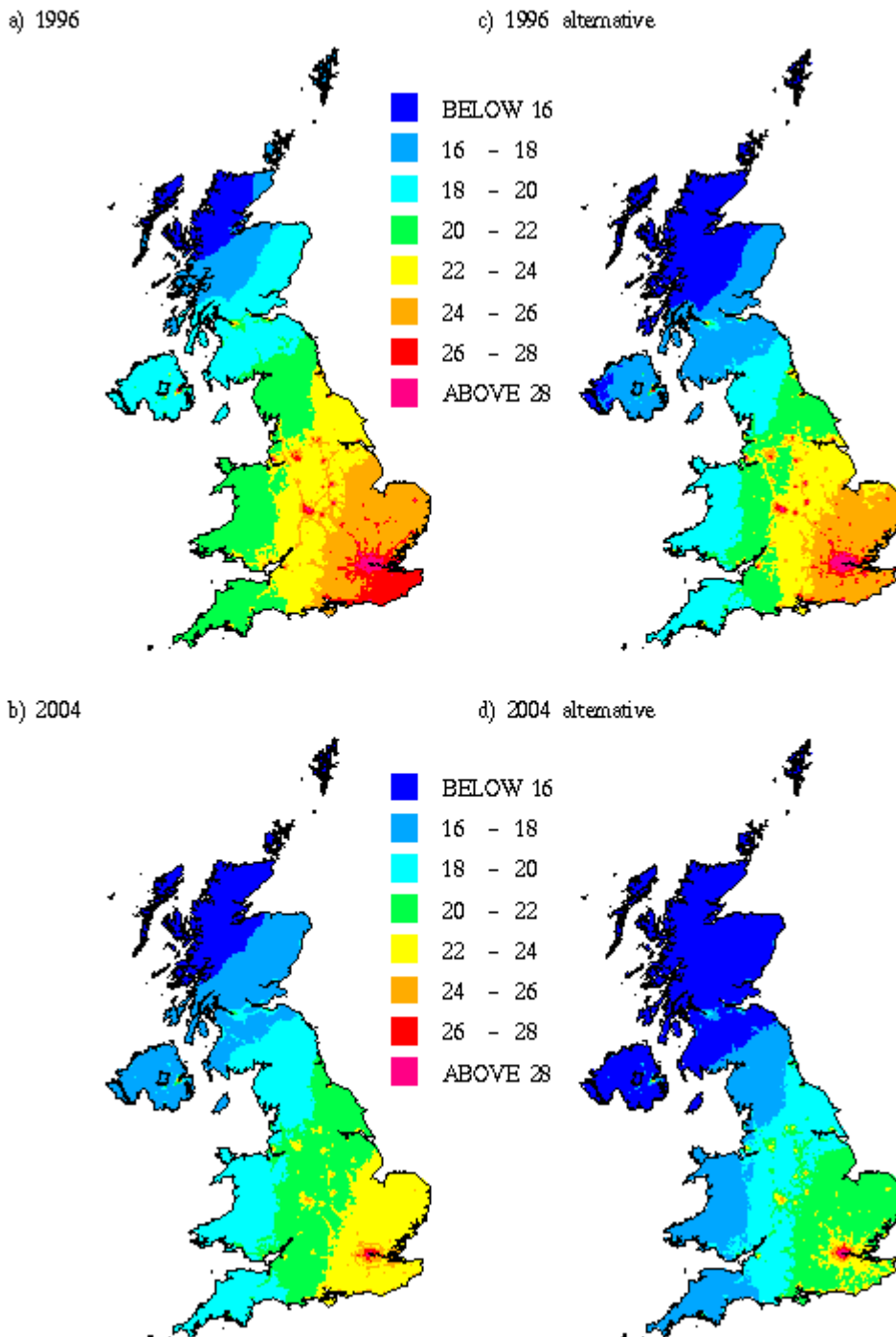
c) 1996 alternative

b) 2004

d) 2004 alternative

Figure 5. Estimated annual mean background PM10 concentrations (ugm-3, gravimetric)