Options for an Exposure-Reduction Approach to Air Quality Management in the UK and the EU for Non-Threshold Pollutants

Air Quality Consultants

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Prepared by

Prof. Duncan Laxen & Stephen Moorcroft

on behalf of

Defra

January 2005

Air Quality Consultants Ltd 12 St Oswalds Road Bristol BS6 7HT
Tel: 0117 974 1086 Fax: 0117 946 6271 E-Mail: DuncanLaxen@aqconsultants.co.uk

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Executive Summary

Options to introduce an Exposure-Reduction approach to supplement the current Limit Value and Emission-Reduction approaches used by the European Union to control exposure to air pollutants are examined in this report. The aim is to maximise the health benefits of measures to control exposure to pollutants that have no established threshold for effect.

The need for a new Exposure-Reduction approach is widely recognised, and has arisen because there is no known threshold for exposure to particulate matter (PM) below which health effects do not occur. The current Limit Value approach tends to focus control of exposure at hot-spots, requiring no measures to reduce exposure where concentrations are below the Limit Value. The Emission-Reduction approach, involving national emission ceilings, brings about a general reduction in concentrations, but is not focussed on minimising exposure in the most efficient way.

This report examines the roles of these three approaches and recognises that each can make an important contribution to controlling exposure to PM (and potentially other non-threshold pollutants). The Exposure-Reduction approach is new, and is therefore considered in detail. Three variants are identified to define exposure, based on modelling, or monitoring using explicit or implicit population weighting. After careful consideration of the advantages and disadvantages of these three variants, it is concluded that an Exposure-Reduction approach based on monitoring could offer the simplest and most practical solution. Closer examination of this approach is carried out, addressing how best to define exposure, how to define the required reduction, and how to measure compliance.

Analysis of PM_{10} monitoring data in the UK is used to help identify some of the requirements for implementation of an Exposure-Reduction approach, in particular, the number of sites necessary to define exposure in a robust way.

A monitoring strategy based broadly on 1 site per million population, applied to agglomerations over 100,000, is suggested as a suitable way to define exposure. It is further suggested that the monitoring is carried out at 'urban' sites, which will need to be carefully defined. It is not considered to be beneficial to include roadside sites, as Limit Values will deal with exposure in such locations. This definition results in around 30 sites being required to represent exposure for the UK. This number of sites would

provide a robust average concentration that would not be sensitive to loss of stations from the specified monitoring network.

An alternative, although less robust approach, would be to use the methodology currently being developed for the European Commission to provide structural indicators for air quality across the European Union.

Careful consideration is given to the option of subtracting 'natural' and 'secondary' PM contributions from the urban exposure value. One option would be to subtract a rural average concentration from the urban values. Whilst this would make the approach more complex, and potentially more difficult to implement, it offers significant scientific benefits. It would focus attention on the PM fraction that is largely within Member States own control, i.e. local primary sources, and avoid problems with variable natural concentrations across Europe. The number of rural sites could be determined on the basis of area, with a country the size of the UK probably requiring around 10-15 sites.

It is proposed that the Exposure-Reduction approach would be best applied to the average concentration across the defined network of monitoring sites. The required reduction could be most effectively determined using the same modelling approach as currently being implemented by IIASA to assist the European Commission with its Clean Air for Europe (CAFÉ) programme. In terms of timing, this may be most appropriately linked with the revision to the National Emissions Ceiling Directive.

The most appropriate Exposure Reduction is likely to be a fixed percentage reduction to be applied to each Member State. This would need to be achieved by a specified date, probably around 10 years after introduction of the new approach.

Compliance checking would be straightforward, clear and transparent. The average concentration across the defined network (after subtraction of rural concentrations, if this option is chosen) in the compliance year would be subtracted from the average across the same network in the base year, to give the reduction actually achieved. This would be expressed as a percentage reduction and compared with the required percentage reduction. To avoid complications due to the natural variability from year to year, due to weather conditions, it is proposed that it would be best to define the exposure as the PM concentration averaged over 3 years, updated on an annual basis.

The report represents the views of the authors and not necessarily those of Defra or the UK Government.

1 Introduction

1.1 Defra has commissioned Air Quality Consultants Ltd to develop options for a methodology to implement an Exposure-Reduction approach for the regulation of air pollutants with no threshold for effects. The need for such an approach has arisen from recent work on ambient particulate matter. There is no convincing evidence of a threshold for health effects arising from exposure to particulate matter (PM) expressed as either PM_{10} or $PM_{2.5}$. The Limit Value approach, which effectively involves a threshold, is not suited to the control of non-threshold pollutants. It is for this reason that the World Health Organisation (WHO) was unable to set a guideline value for PM (WHO, 2003).

1.2 The limitations of the Limit Value approach were also recognised by the European Commission (EC) Working Group on Particulate Matter, when it prepared its recent report (EC, 2004). The Group recommended that an approach based on population exposure be developed to supplement the Limit Value approach (see Appendix 1). More recently the UK Air Quality Expert Group was asked to consider the differences between strategies that address hotspots of exceedence and those that aim to reduce population exposure. The Expert Group concluded that a strategy based on reducing exposure to the largest population would seem to offer improved benefits to public health, and recommended further work on developing such a strategy (see Appendix 2). The Workshop on Review & Assessment of European Air Pollution Policies, held in Gothenburg 25-27 October 2004, also endorsed the view that an Exposure-Reduction approach was required, especially for PM, and recommended that the EC develop a suitable approach to form part of its Thematic Strategy for Clean Air for Europe (CAFÉ). The European Federation of Clean Air and Environmental Protection Associations (EFCA) has recently written to the European Commission to recommend that "*Member States request DG ENV to include in the Thematic Strategy on Air Pollution …. the intention to explore approaches, additional to the system of limit values, with the aim to increase the protection of the population as a whole against presently regulated pollutants*."

1.3 The objective of this report is to set out options for policy makers to maximise the efficiency with which control measures minimise the health impacts to the population at large of exposure to non-threshold pollutants, i.e. the approach that will maximise the reduction in the number of deaths, hospital admissions etc. related to air pollutants. This report specifically considers how an Exposure-Reduction approach might be applied to PM (either PM_{10} or $PM_{2.5}$), but it is recognised that the approach could equally be used for other non-threshold pollutants. The report sets out the range of approaches available to control exposure to PM, analysing their strengths and weaknesses, and then identifies the option or options that are likely to prove workable both at the UK and EU level. The first part of the report outlines the current system of Limit Values, introduces three ways to apply an Exposure-Reduction approach, and finally deals with options for Emission-Reduction. In the second part of the report, more detailed consideration is given to the practicalities and options for an Exposure-Reduction approach based on monitoring.

1.4 A distinction is drawn between approaches aimed at:

- maximising the efficiency, which relates to the ability to maximise health benefits across the population, e.g. life-years saved or hospital visits avoided;
- maximising the equity, whereby the individuals most at risk through exposure to the highest concentrations are protected to a uniform minimum standard.

1.5 The assessment deals with practical aspects of implementing the different approaches, including the important issue of monitoring compliance.

1.6 The views expressed and conclusions reached are those of the authors and not necessarily those of Defra or the UK Government.

2 Approaches

2.1 There are three general approaches available to control exposure to PM (Figure 1). These are summarised below, and then discussed in greater detail in the next section. It is important to note that these approaches are not mutually exclusive. It may be appropriate to consider a ‘basket’ of approaches to control exposure to pollutants, from which suitable options are selected according to the nature of the individual pollutant.

2.2 It is recognised that various regulations, including emission limits for different source categories, e.g. vehicles and large combustion plant, also control PM. However, these regulations are not directly related to the control of public exposure and consequential health risk of the population, and are not therefore a suitable mechanism within the scope of this report.

A) Limit Values

2.3 Limit values are a cornerstone of the current approach to the control of exposure to pollutants in Europe. They set the concentration of the pollutant not to be exceeded anywhere in a Member State, and include a date from which this is to be achieved. This approach is focussed on hot-spots, i.e. those places where concentrations are highest. For PM, it is necessary to take account of the wide range of sources contributing to PM concentrations, the variability of regional concentrations across Europe and the local enhancement near to sources.

2.4 The current system of Limit Values applies everywhere including locations close to busy roads. It would be possible to focus the Limit Values away from hot-spots if compliance were to be based on monitoring or modelling for urban background locations. Both the current hot-spot approach and a modified urban background approach will be considered in greater detail.

2.5 Compliance for the PM Limit Values is based on monitoring, although this may be supplemented by modelling techniques to provide an adequate level of information, or where levels are sufficiently low.

B) Exposure Reduction

2.6 There are three principal approaches that could be applied to an Exposure-Reduction approach:

- an approach based on modelling of exposure to ambient concentrations. This would readily lend itself to a population-weighted approach, as modelled concentration fields could easily be combined with spatial population data, to allow a population-weighted target to be derived. Compliance would be by way of emission inventories and modelling. There are two variants:

- a spatial resolution covering only background concentrations;
- a spatial resolution explicitly including roadside concentrations.

- an approach based on monitoring. This could operate in two different ways:
  - with concentrations population-weighted;
  - based on a selected set of monitoring sites with no explicit population weighting.

In each of these cases, there could be three variants to the way in which the Exposure Reduction is evaluated:

- based on total exposure concentration;
- using exposure concentration minus the rural concentration;
- using exposure concentration minus the rural concentration, but with the rural sulphate and nitrate[1] added back, to approximate total anthroprogenic concentrations.

Compliance would be based on monitoring.

C) Emissions Reduction

2.7 This approach essentially incorporates PM into the National Emissions Ceiling (NEC) Directive. Secondary PM is already covered indirectly by the NEC Directive, thus the application within an Emissions-Reduction approach is assumed to incorporate primary PM. The NEC Directive currently sets absolute reduction targets, in tonnes per year, but this could be amended to percentage reductions. Compliance is determined through emission inventories. There are two variants that could be applied:

- based on all primary PM sources;
- targeted at primary PM sources near ground level.

[1] The sulphate and nitrate concentrations in this context are assumed to represent the anthropogenic transboundary component.

3 PM Specific Issues

3.1 The following factors need to be borne in mind when developing strategies to control PM.

- There are many anthropogenic sources of PM;
- Some of the anthropogenic sources are still poorly understood, in particular resuspension from roads;
- There are significant natural sources of PM;
- There are significant secondary sources of PM;
- Long-range transport is important for PM, especially for secondary PM;
- The new focus is likely to be on $PM_{2.5}$, for which there has been little monitoring to date;
- It is believed that health impacts are much greater from long-term (annual mean) exposure to PM than from short-term (24-hour) exposure;
- There are large variations in rural background concentrations across Europe;
- Roadside concentrations are typically only 20-30% higher than local background concentrations;
- Local background concentrations are usually dominated by the contribution from the regional background.

4 Analysis of Available Approaches

This section sets out in greater detail the various approaches that are available, and considers the advantages and disadvantages of each in terms of their application to PM.

A) Limit Values

4.1 The current system of air quality control is very much driven by air quality Limit Values, which are set out in Daughter Directives to a Framework Directive that establishes the principles for this approach. For instance, the Auto-Oil programme carried out on behalf of the European Commission was based on introducing emission controls so as to meet the air quality Limit Values. This is not the place for a detailed evaluation of this approach, but it is recognised that the approach inevitably tends to focus control measures on those locations where concentrations are highest. In many circumstances for PM, this will be locations alongside busy roads. However, it is now recognised that concentrations at the roadside are determined more by the local background than the emissions from the road itself. This local background is itself determined by urban scale emissions and by regional, national and international emissions, a significant proportion being natural sources. This local background varies across Europe, in particular in terms of natural sources.

4.2 An important aspect of the Limit Value approach is that it provides equity of health risk, in that every individual within the European Union is afforded protection from exposure to air pollution to a uniform, minimum standard. In addition, Limit Values play an important role in permitting procedures for industrial operations, and they are also used to assess the air quality impacts of development proposals, for example within Environmental Impact Assessments. The advantages and disadvantages of the Limit Value approach are summarised in Table 1, both in general terms and applied specifically to hot-spot or urban background locations.

Table 1 Advantages and Disadvantages of Limit Values

Advantages	Disadvantages
A) General	
Provides a cap on the individual risk of health effects for people exposed in hot-spots. Equality of protection anywhere in Europe. Provides a clear basis for assessment of compliance. Relatively simple to implement and understand, including presentation to members of the public. Provides a clear basis for permitting procedures and EIA.	No requirement to reduce exposure where the Limit Value is not exceeded. General exposure to PM can creep up, as long as the Limit Values are not exceeded at hot-spots. Particularly sensitive to annual variations due to meteorology.
A1) Hot-spots	
Provides a cap on the individual risk of health effects for people exposed in hot-spots. Protects individuals exposed to the highest concentrations and hence greatest risk.	Difficult to define a monitoring programme to ensure equitable application across Europe. Difficult to use modelling as a compliance tool due to small spatial scale of exceedence areas, and problems of modelling in dense urban settings. Long-term exposure to PM is more significant in health terms and this is not efficiently dealt with by reducing hot-spot exposure. As the Limit Value currently applies everywhere, then it may be unrelated to long-term exposure. The nature of a roadside site could change radically without reflecting a change to general roadside environments, e.g. in an extreme case a road could be pedestrianised. Concentrations would decline such that the Limit Value could be met, but this would not reflect a general reduction in population exposure.
A2) Urban Background	
Focuses control on those areas where most people are exposed to PM. Easier to define monitoring sites to ensure equitable application across Europe. Consistent with the data used in epidemiological studies.	Not equitable, as it ignores the additional risk for people living at the roadside.

B) Exposure Reduction

4.3 The underlying principle for an Exposure-Reduction approach is that the best way to maximise health benefits for non-threshold pollutants is to ensure an overall reduction in exposure, irrespective of the concentration. This is illustrated with the following calculation for exposure to PM: the health benefits of reducing the average exposure of 10 million people by 1 μg/m^3 are one hundred times greater than reducing the exposure of 10,000 people by 10 μg/m^3.

4.4 There are three variants by which this can be achieved, as discussed below, but the basic premise for all three is:

- current exposure to PM will be defined for each Member State;
- each Member State will be required to reduce this exposure by a given date.

B1 Modelling

4.5 One of the options is to define exposure using modelling. The aim would be to produce a population-weighted average concentration. This could be achieved using GIS to combine concentration maps with population maps.

Table 2 Advantages and Disadvantages of Exposure Reduction by Modelling

Advantages	Disadvantages
B1) General	
Ensures that reductions in exposure to PM are required even where the Limit Value is not exceeded. Readily excludes natural background, thus focusing on the sources that can be controlled. It should be relatively easy to derive a population-weighted concentration.	Requires a good quality emission inventory spatially disaggregated across the Member State. This may be difficult to achieve. Population weighting may be difficult in some Member States if population data are not in GIS format. Emission inventories evolve with time and availability of new data and greater understanding of sources. This would require regular backward re-scaling of the concentrations. Imposition of one model would be difficult. Use of different models could give different result, leading to lack of equity between Member States. Models would require verification of three components – regional transport of secondary PM – urban background – roadside (open and canyon like) to an agreed standard. Compliance checking would be dependent entirely on emission inventories.
B1a) Urban Background	
Matches the approach being developed by IIASA to support the CAFÉ programme.	Excludes exposure of the population near to roads, where individuals may be at greater risk.
B1b) Urban Background + Roadside	
More inclusive than B1a.	Requires modelling to a very fine spatial scale.

B2 Monitoring – Population Weighted

4.6 The aim would be to derive a population-weighted exposure based on monitoring results. To do this a monitoring station would have to be taken as being representative of a given population. However, it is likely to be difficult to define accurately the population exposure represented by an individual monitoring station[2]. This would require a large number of monitoring stations.

4.7 It would also be possible to exclude the natural background and secondary PM by subtraction of a rural background. This rural background would need to be derived individually for each exposure monitoring station. It would also be possible to include the secondary PM component by measurement of rural sulphate and nitrate. In addition, it would be possible to allow for the additional exposure at the roadside.

Table 3 Advantages and Disadvantages of Exposure Reduction by Population-Weighted Monitoring

Advantages	Disadvantages
B2) General	
Ensures that reductions in exposure to PM are required even where the Limit Value is not exceeded.	Additional monitoring requirements within some agglomerations. Difficult to accurately define the population-weighted exposure represented by an individual monitoring station. Potential problems if sites close, or fail to meet the data capture requirements. Probably require stricter definition of monitoring site classification. May require re-definition of agglomerations in order to ensure that significant population areas are not excluded from the assessment. May require the use of running-mean concentrations over several years in order to avoid meteorological influences. Need to deal with sites with missing data in a particular year or site characteristics changing.
B2a) Urban Background	
Relatively straightforward to introduce, as urban background monitoring likely to be in place for compliance checking of Limit Values.	

[2] Structural indicators for PM health effects are currently being developed by the Commission. A methodology to define the population-weighted exposure of the urban population to PM has been developed by the European Environment Agency. This approach could also be adopted for Exposure Reduction (see Section 5).

Table 3 Contd.

B2b) Urban Background minus Rural	
Exclusion of transboundary component would allow Exposure-Reduction targets within the direct control of the Member State to be established. Avoids problems of natural PM that is outside the control of Member States and which is variable across Europe.	Requires appropriate rural monitoring. Introduces additional complexity into the approach.
B2c) Urban Background minus Rural plus Sulphate and Nitrate	
Focuses controls on all anthroprogenic sources of PM, both primary and secondary.	Requires monitoring for sulphate and nitrate at all rural sites. Currently there is little monitoring of sulphate and nitrate in EU Member States (Appendix 7). Requires adjustment of sulphate and nitrate results to approximate PM equivalent. Introduces additional complexity into the approach.
B2d-f) As Above plus Roadside	
Allows for exposure to higher concentrations near to roads.	Difficult to define representative sites to cover roadside exposure. Difficult to define population exposed in the roadside environment. What distance is described as roadside – out to 50 m, out to 100 m? Would probably require roadside sites in every agglomeration. The nature of a roadside site could change radically without reflecting a change to general roadside environments, e.g. in an extreme case a road could be pedestrianised. Concentrations would decline but would not reflect a general reduction in population exposure.

B3 Monitoring

4.8 The aim of a monitoring approach is similar to that described in B2 above, but does not attempt to *explicitly* weight the exposure according to population. Instead, it is envisaged that the requirement would be to set criteria for the number of monitoring stations to be included in the exposure calculation, according to the population, e.g. within agglomerations. There is thus an *implicit* element of population weighting in the calculation.

4.9 As in B2 above, it would be possible to exclude the natural background and/or anthroprogenic transboundary component (represented by sulphate and nitrate concentrations). It would also be possible to allow for a roadside contribution.

Table 4 Advantages and Disadvantages of Exposure Reduction by Monitoring

Advantages	Disadvantages
B3) General	
Ensures that reductions in exposure to PM are required even where the Limit Value is not exceeded. No need to explicitly define the population-weighted exposure.	Additional monitoring requirements within some agglomerations. Probably require stricter definition of monitoring site classification. May require re-definition of agglomerations in order to ensure that significant population areas are not excluded from the assessment. May require the use of running-mean concentrations over several years in order to avoid meteorological influences. Need to deal with sites with missing data in a particular year or site characteristics changing.
B3a) Urban Background	
Relatively straightforward to introduce, as urban background monitoring likely to be in place for compliance checking of Limit Values. Compliance checking is straightforward.	
B3b) Urban Background minus Rural	
This excludes secondary PM that is best dealt with by NEC.	Requires appropriate rural monitoring Introduces additional complexity into the approach.
B3c) Urban Background minus Rural plus Sulphate and Nitrate	
Focuses controls on all anthroprogenic sources of PM, both primary and secondary.	Requires monitoring for sulphate and nitrate at all rural sites. Currently there is little monitoring of sulphate and nitrate in EU Member States (Appendix 7). Requires adjustment of sulphate and nitrate results to approximate PM equivalent. Introduces additional complexity into the approach.
B3d-f) As Above plus Roadside	
Allows for exposure to higher concentrations near to roads.	Difficult to define representative sites to cover roadside exposure. Difficult to define population exposed in the roadside environment. What distance is described as roadside – out to 50 m, out to 100 m? Would probably require roadside sites in every agglomeration. The nature of a roadside site could change radically without reflecting a change to general roadside environments, e.g. in an extreme case a road could be pedestrianised. Concentrations would decline but would not reflect a general reduction in population exposure.

C Emissions Reduction

4.10 The National Emissions Ceiling (NEC) approach has been developed as a key element in the control of acid deposition and ozone. It is aimed at the control of secondary pollutants that have a major transboundary component. Differentiated emissions reduction targets are set for each Member State with the aim of achieving specified environmental targets (Appendix 3). These targets have been set using the RAINS model[3]. This approach already deals indirectly with secondary PM formed from sulphur dioxide, nitrogen oxides and ammonia emissions, however, there is the option to extend the NEC approach to incorporate primary PM.

4.11 A project to support the review of the NECD is currently being undertaken by Entec UK Limited on behalf of the European Commission. The outcome of this project will not be known until early 2005, but it is understood that the feasibility of introducing an emissions ceiling for primary PM forms one of the tasks that is being considered (see Appendix 4).

4.12 An important issue related to primary emissions is that of relating emissions to exposure concentrations. For instance, emissions from tall stacks have a very different impact on exposure concentrations compared to ground-level emissions, while emissions on motorways in the middle of the countryside have little impact on exposure compared to emissions from roads in urban areas. These problems are specific to primary PM and do not apply to ozone and acid deposition. In order to overcome some of these limitations a variant on the reduction of total emissions is considered, whereby the emission reductions are targeted on specific sectors. This issue may also be tackled in the NECD review described above.

C1 NEC for Total PM Emissions

4.13 At its simplest, this approach would require a Member State to reduce total primary PM emissions from all sources by a fixed percentage.

C2 NEC for Targeted PM Emissions

4.14 A modification of the total emissions approach would be to target the emission being controlled to those more significant for the exposure of the greatest number of people. At its simplest it would be sufficient to target just traffic emissions.

3 This is the model that underlies the IIASA studies being undertaken for PM in the CAFÉ programme.

Table 5 Advantages and Disadvantages of National Emissions Ceiling Approach.

Advantages	Disadvantages
C) General	
Relatively straightforward to introduce. Deals with both national and transboundary PM.	There are still important primary PM emissions that are not well understood. As new knowledge on emissions arises then the emissions calculations would require changing Not very transparent for the public.
C1 Total PM Emissions	
Reduces the total atmospheric burden of PM.	Poorly related to exposure – a significant reduction in emissions from tall stacks at power stations would have minimal impact on population exposure.
C2) Targeted PM Emissions	
Targeting emissions near to the ground links the emission reductions more closely to exposure.	If focused on traffic then fails to deal with other sources, including domestic and fugitive emissions. If fugitive emissions included, then could potentially achieve reduction by focussing on fugitive sources which are well away from populations. Could achieve required emissions reductions by focussing on emissions from roads outside urban areas, thus not greatly reducing exposure.

Recommended New Approach

4.15 The advantages and disadvantages of the different approaches are summarised in Table 6. There are clearly strengths and weaknesses of each of the approaches. A clear weakness of the Limit Value approach is that it is not an efficient way to maximise the reduction of health effects arising from exposure to PM. The Limit Value approach does though have distinct advantages; it has an element of equitability, in that it provides an upper limit to the risk that individuals will be exposed to, and it is easy to understand. It is particularly well suited to controlling short-term exposure, and provides a benchmark for reporting pollution levels to the public and assessing monitoring results.

4.16 The Exposure-Reduction and National Emission Ceiling approaches, on the other hand, offer better ways to maximise health benefits. Of these two approaches, it is considered that the Exposure-Reduction approach provides a more optimal route to controlling PM health impacts arising from primary PM emissions. The National Emission Ceiling approach is better suited to controlling exposure to secondary PM, although the potential to incorporate emission ceilings for primary PM is currently being considered.

4.17 As all three approaches, Limit Values, Exposure Reduction and Emissions Reduction (i.e. National Emissions Ceilings), have different roles to play, it is envisaged that all three could be usefully developed in parallel. (The timing of the development of these three approaches in relation to the timetable of the CAFÉ Thematic Strategy is discussed in section 6.6). Limit Values provide protection, on an equitable basis across Europe, to those individuals exposed to the highest PM concentrations, and hence those at greatest risk of experiencing health effects. National Emission Ceilings ensure that emissions of secondary PM precursors are reduced, and may be developed further to include primary PM emissions. However, measuring the impact of National Emissions Ceilings in reducing actual PM exposure is not straightforward, and there is a clear case for an Exposure-Reduction approach to be developed in tandem. This would be analogous to Limit Values driving emission controls via the Auto-Oil programme.

4.18 The Exposure-Reduction approach is essentially a new approach, and thus deserves careful consideration. Three variants for the Exposure-Reduction approach have been identified. At this point in time it is considered that the modelling of Population-Weighted Exposure would not be a practical approach for the reasons set out above. It is therefore recommended that the Exposure-Reduction approach is taken forward using a simpler monitoring-based approach – essentially variants B2 or B3 as discussed above. The implementation of an Exposure-Reduction approach based on monitoring is explored in greater detail in Section 5.

Table 6 Summary of Advantages and Disadvantages of Different Approaches

	Approach	Maximising Population Health Benefits (Efficiency)	Maximising Individual Health Benefits (Equity)	Ease of Application	Understandable by Public
A	**Limit Values**				
Aa	Hot-spots	✓	✓✓✓✓✓✓✓	✓✓✓✓	✓✓✓✓✓✓✓
Ab	UB	✓✓✓	✓✓✓	✓✓✓✓✓	✓✓✓
B	**Exposure Reduction**				
B1	**Modelling Population Weighted**				
B1a	UB	✓✓✓✓✓✓✓	✓✓✓	✓✓✓	✓✓✓
B1b	UB + Road	✓✓✓✓✓✓✓✓	✓✓✓✓	✓✓	✓✓✓✓
B2	**Monitoring Population Weighted**				
B2a	UB	✓✓✓✓✓	✓✓✓	✓✓✓✓	✓✓✓
B2b	UB – Rural	✓✓✓✓✓✓	✓✓	✓✓✓	✓✓
B2c	(UB – Rural) + SO_4 + NO_3	✓✓✓✓✓✓✓	✓	✓✓	✓
B2d	UB + Road	✓✓✓✓✓✓	✓✓✓✓	✓✓✓✓✓	✓✓✓✓
B2e	(UB + Road) – Rural	✓✓✓✓✓✓✓	✓✓✓	✓✓✓✓	✓✓✓
B2f	((UB + Road) – Rural) + SO_4 + NO_3	✓✓✓✓✓✓✓✓	✓✓	✓✓✓	✓✓
B3	**Monitoring**				
B3a	UB	✓✓✓✓	✓✓✓	✓✓✓✓✓✓	✓✓✓✓✓✓
B3b	UB – Rural	✓✓✓✓✓	✓✓	✓✓✓✓✓	✓✓✓✓
B3c	(UB – Rural) + SO_4 + NO_3	✓✓✓✓✓✓	✓	✓✓✓	✓✓✓
B3d	UB + Road	✓✓✓✓✓	✓✓✓✓	✓✓✓✓	✓✓✓✓✓✓✓
B3e	(UB + Road) – Rural	✓✓✓✓✓✓	✓✓✓	✓✓✓	✓✓✓✓✓
B3f	((UB + Road) – Rural) + SO_4 + NO_3	✓✓✓✓✓✓✓	✓✓	✓	✓✓✓✓
C	**National Emission Ceiling**				
C1	Total PM	✓✓✓	✓	✓✓✓	✓
C2	Targeted PM	✓✓✓✓	✓✓✓	✓✓	✓✓

UB = Urban Background Road = Roadside Rural = Rural Background SO_4 = Sulphate NO_3 = Nitrate

5 Practicalities of an Exposure-Reduction Approach

Introduction

5.1 This section examines the practicalities associated with introducing an Exposure-Reduction approach based on monitoring, to complement Limit Values and National Emissions Ceilings. Wherever possible, the intent has been to build upon existing requirements and strategies in order to minimise the impacts and costs of implementation. Available PM_{10} data will be used to illustrate the issues. However, it may be considered more appropriate to introduce the new Exposure-Reduction approach for $PM_{2.5}$. Some consideration of timescales for implementing an Exposure-Reduction approach for PM is provided at the end of this section.

5.2 Issues that need to be addressed in order to develop a practical Exposure-Reduction approach are set out in Figure 2. They deal with:

- the monitoring data to be used to define exposure;
- the approach required to determine the reductions in exposure to be applied to Member States;
- the requirements for compliance checking.

Defining Exposure by Monitoring

5.3 As described in Section 4, two approaches could be used to define exposure based on monitoring. The first explicitly weights the measured PM concentrations according to an estimate of the population exposed to that concentration. Such an approach is currently being considered by the European Commission for the calculation of structural indicators (see Appendix 5). In this case, the population attributed to each measurement station is to be defined as that living within a 3 km radius of the station. An average concentration for a Member State is then calculated across all the measurement stations, weighted by population. Such an approach, if implemented for the structural indicators, could be adopted to define exposure in the Exposure-Reduction approach[4].

[4] The structural indicators are by definition suitable as 'indicators' of changes in exposure. They have not though been developed to provide an appropriate definition of exposure for a formal Exposure-Reduction approach to pollution control, to be implemented as an EU Directive. The proposal for structural indicators is based on use of available data for urban background sites, the number of which is limited in countries that have focussed their monitoring on hot-spot sites. Limitations of the current networks include the fact that: a) the number of sites is not necessarily related to population, e.g. two sites could represent an urban area with 10 million with one site representing 1 million, thus the greatest weight would be given to the smaller urban area; and b) the population

5.4 A more robust option would be for exposure to be defined as the average annual-mean concentration for a carefully specified set of urban background monitoring stations[5]. It is considered that this approach would be the most practical and simple to implement across 25 Member States. Such a set of sites could form the basis for more robust structural indicators[6].

5.5 The aim is to link this measure to the average exposure of the population, but without explicit population weighting. This is best achieved by using monitoring sites in urban background locations, with the number of monitoring sites being linked to the population. The current Framework Directive defines agglomerations as being urban areas with over 250,000 people. The Directive on the Assessment and Management of Environmental Noise goes further and includes in the definition of agglomerations urban areas with a population over 100,000. In the UK there are 28 agglomerations with over 250,000 people accounting for 43% of the UK population and a further 40 between 100,000 and 250,000 accounting for a further 10 % of the UK population[7]. Member States will thus already have defined their agglomerations, and this could provide the basis for Exposure-Reduction monitoring requirements.

5.6 The other factor to take into account is that the uncertainty in the average UK exposure depends on the number of sites used to derive this average. This is illustrated in Figures 3 and 4, which show that the envelope of average concentrations from 43 randomly averaged urban background, urban centre and suburban sites throughout the UK narrows as the number of sites increases, such that once there are more than 20 sites the UK average will be defined to within ±5%. This reduces to 15 sites when the site types are more closely defined as urban centre[8] (Figures 5 and 6). As the geographic scope is reduced then the number of sites required for the mean to be within ±5% of the final mean is reduced still further, such that for urban background and suburban sites in London it is down to 10 (Figure 7).

5.7 Taking into account the two pieces of information set out above, **it is suggested that a monitoring strategy based broadly on 1 site per million of population applied to agglomerations over 100,000 would be suitable, i.e. 30 sites in total for UK agglomerations**[9]. There would thus be 8 sites in the Greater London urban area, 2 in each of

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within 3 km in a city of 5 million could be 20,000 because of where the monitor has been placed, while in a city of 0.5 million the population within 3 km could be 60,000. The greatest weight will thus be given to the concentration in the smaller urban area. Some of these limitations of the structural indicator could be addressed with the introduction of the new Exposure-Reduction approach, which would give a more robust measure of exposure.

5 This approach could be applied to the results for each monitoring station separately rather than to the average. This option is dealt with in the section on Defining the Required Reduction.

6 A summary of current urban background PM_{10} monitoring sites in Europe is provided in Appendix 6

7 King and Bush (2001) Identifying the Options Available for determining Population data and Identifying Agglomerations in Connection with EU Proposals Regarding Environmental Noise, AEAT.

8 Sites defined as 'Urban Centre' may be relatively close to busy roads, i.e. as close as about 20 m.

9 A reason for extending the number to 30 rather than the 15 suggested in para 5.5 is discussed later in the section on Subtraction of Natural and Secondary Contributions.

the West Midlands and Greater Manchester urban areas and 1 each in West Yorkshire, Glasgow, Tyneside and Liverpool urban areas (16 sites). The remaining sites would be distributed across the remaining agglomerations selected on the basis of 1 site for every two agglomerations between 250,000 to 750,000 (11 sites), and 1 site for every 8 agglomerations between 100,000 and 250,000 (5 sites). To ensure a representative distribution of these remaining sites the agglomerations should be grouped geographically before one agglomeration within this group is selected to have a monitoring station.

5.8 A clear limitation of this approach is that it does not take into account:

- all individual agglomerations;
- the 47% of the population (in the UK) that lives outside agglomerations >100,000.

5.9 This limitation means that a control strategy could in theory be focused on the 23 agglomerations in which monitoring is carried out, thus not benefiting those in the agglomerations without monitors or in areas outside of agglomerations. One way around this would be to require a number of monitoring sites in urban areas with populations of <100,000 people, with sites chosen in a similar way to the sites for agglomerations with 100-250,000 people and/or to require at least one monitoring station in each agglomeration. At this point in time such an approach is not recommended, as it would add to the complexity and to the number of monitoring sites[10].

Type of Monitoring Stations

5.10 The focus should be on concentrations that best represent the average exposure of the greatest number of people within each agglomeration. This is believed to be best accomplished by using sites broadly meeting the 'urban centre' definition as used in the UK: *a non-kerbside site located in an area representative of typical population exposure in town or city centres. This is likely to be strongly influenced by vehicle emissions, as well as other general urban sources of pollution. Sampling at or near breathing-zone heights will be applicable (Defra, 2003).* This definition, as currently applied in the UK, allows sites relatively close to busy roads, i.e. to within 20 m[11]. This is considered to be too close for the new approach, as the site would be too strongly influenced by a source that could easily change with time for whatever reason. It is thus **suggested that 'Urban' sites are defined as: *sites located in an area representative of typical population exposure in urban areas. They should be no closer than 100 m to a very busy road***

10 To extend the zones and agglomerations concept underlying the Framework Directive, it is possible to envisage the non-urban sites being defined on a per-zone basis. This would though suffer from the fact that zones are defined differently by each Member State, thus it would be difficult to harmonise the system.

11 Appendix A1 to LAQM.TG(03), Box A1.2 (Defra, 2003).

(>40,000 veh/d), 75 m to a busy road (20-40,000 veh/d), 50 m to a fairly busy road (10-20,000 veh/d) and 25 m from any other road. Where only one site represents an agglomeration, it should be within the inner one-third of the radius of a circle representing the extent of the urban area.

5.11 Consideration also needs to be given to whether roadside sites should be included in the assessment of exposure. Their inclusion would be designed to reflect the additional exposure in such situations. If they are to be included, then the number of sites would need to be broadly in proportion to the population living close to busy roads (possibly defined as roads with >10,000 veh/d). Such roads could be taken to influence concentrations out to 50 m from the edge of the road. If it is assumed that 5% of the population live in such areas, then roughly 1 in 20 of the monitoring sites should be roadside. If, on the basis set out above, the UK urban exposure is to be defined by 30 sites, then around 2 would need to be roadside. Inclusion of roadside sites would be difficult for the following reasons:

- it would be difficult to determine two suitable representative roadside sites;
- roadside concentrations are highly variable from site to site, depending on the traffic flow on the nearby road and on the exact distance from the road;
- it would be easy to influence the outcome of the Exposure Reduction by changing the immediate environment of the road alongside the monitoring site, e.g. by pedestrianising the road.

5.12 On balance, it is considered that there would be no great benefit from including roadside sites[12].

Subtraction of Natural and Secondary Contributions

5.13 There are considered to be significant scientific benefits to be derived from subtracting a rural background, although it is accepted that this would make the system more complex, and potentially more difficult to implement. Subtraction of the rural background would:

- give a concentration that equates more closely to the proportion of PM that is locally controllable;
- produce greater equity for Member States with very different background concentrations, a large part of which will be due to natural sources;

[12] This might be different if it is decided not to include Limit Values for hot-spots, such as roadside locations.

- produce a higher figure for the percentage reduction, which would better reflect the effort required by the Member State. It should be more understandable by the public.

5.14 These issues are illustrated by the examples in Table 7.

Table 7 Illustration of Impacts of Removing Rural Background

	Member State 1	Member State 2
Rural Background (Base Year)	5 μg/m^3	15 ug/m^3
Urban Increment (Base Year)	14 μg/m^3	7 μg/m^3
Urban Total (Base Year)	19 μg/m^3	22 μg/m^3
Required Urban Increment Reduction (%)	25%	25%
Rural Background (Compliance Year)	4.7 μg/m^3	14.3 μg/m^3
Urban Increment (Compliance Year)	11.5 μg/m^3	5.25 μg/m^3
Urban Total (Compliance Year)	16.2 μg/m^3	19.55 μg/m^3
Exposure Reduction Urban Increment	3.5 μg/m^3	1.75 μg/m^3
Exposure Reduction Total [a]	3.8 μg/m^3	2.45 μg/m^3
Exposure Reduction (% of Urban Total [b])	20%	11%

[a] Reduction from base year in total concentration in compliance year.

[b] Reduction as percentage of base year total.

5.15 A disadvantage of this approach is that additional rural monitoring stations would have to be established[13], although such stations are required anyway to develop an appropriate understanding of PM. It could, on the other hand, be possible to develop a procedure to model rural background, although monitoring would still be required to verify the model, and this procedure would not allow readily for variable meteorological influences on both urban and rural sites[14].

5.16 The minimum number of sites required to define a national rural background with reasonable certainty, to be subtracted from the national urban-exposure concentration, is expected to be similar to that found for urban centre sites, probably of the order of 10-15 sites for the UK. In a Member State with a much smaller geographic area, then a smaller number of sites should suffice, as the range of rural concentrations would be expected to be smaller. It may be best to develop a criterion for the number of rural sites based on the area of the country. It is thus **suggested that if subtraction of the rural background were included, this be defined by of**

[13] A summary of existing rural monitoring stations in Europe is provided in Appendix 6.

[14] The measured urban sites would be influenced by meteorology, while the modelled rural sites would not, unless very sophisticated modelling was applied.

the order of 10-15 rural sites in the UK and that this number is related to surface area in order to derive a suitable number for other Member States, with a minimum of 5 sites[15]. It may be possible for a Member State to use results from nearby sites in neighbouring countries. This number of sites is considered appropriate, to provide a stable rural concentration to subtract from the urban concentration (allowing for loss of sites in a particular year) and to allow for the geographic variation over a country the size of the UK. These sites will also provide invaluable information on regional PM concentrations, which is essential to a proper understanding of, and capability to model, PM in urban areas. There are currently only 4 rural PM_{10} sites in the UK (a 5th has just been established). The UK's Air Quality Expert Group recently concluded that this number of rural monitoring sites was inadequate, and recommended a significant expansion of the rural network[16].

5.17 A variant on this approach would be to subtract the rural background less the PM due to sulphate and nitrate, i.e. to determine the Exposure concentration as the urban concentration minus the rural concentration, with the measured sulphate and nitrate at the rural location then added on, after conversion to a PM equivalent. This would be closer to an exposure concentration related to all anthroprogenic sources. This is not, however, considered to be an option to pursue for several reasons:

- The sulphate and nitrate represent secondary PM, which is best controlled by the National Emissions Ceiling approach;
- The measurement of sulphate and nitrate would add significantly to the complexity of the measurement requirements. There are currently only a few stations measuring rural sulphate and nitrate in Europe (see Appendix 7);
- Assumptions would have to be made as to the chemical composition of the sulphate and nitrate particles to generate a PM equivalent concentration;
- A large part of the secondary PM is outside the control of individual Member States.

5.18 It should be noted that subtraction of a rural-mean background leads to greater uncertainty in the average exposure concentration, requiring a greater number of monitoring sites to arrive at a given level of uncertainty. This is illustrated in Figure 8 and 9, where a mean rural background for the UK of 15.7 $\mu g/m^3$ has been subtracted from the average of randomly selected sites. These figures may be compared with Figures 5 and 6. The average Exposure concentration

[15] This minimum is to ensure that sufficient data are available in the event that there are problems at one or more sites leading to data loss.
[16] Report available at www.defra.gov.uk/environment/airquality/aqeg/.

when averaging 10 sites out of 19 is within ± 20% of the overall average, in the case of background subtraction, while it is ±7% for total concentrations. This added uncertainty with rural background subtracted justifies the use of 30 sites to represent the UK average PM exposure concentration (see para 5.6).

Changes in Sites and Missing Data

5.19 The system would need to cope with changes to sites and loss of data due to poor data capture, for whatever reason. Temporary changes to the environment around a monitoring site, e.g. a major construction site established nearby, such that PM concentrations are elevated slightly over a year before settling down to pre-construction levels, and poor data capture, can be dealt with by interpolating for the missing or discounted year[17].

5.20 The permanent loss of a site would be harder to handle. The best way would be to back-calculate the average for the network without the lost site. There would therefore be a newly defined Exposure-Reduction network. If a new site is added to the network then the best approach will be to interpolate the data for previous years at this new site once two years of data are available[17].

5.21 These problems add to the justification for a larger rather than smaller number of monitoring sites for the Exposure-Reduction network, and for the averaging of concentrations across sites, as one site with interpolated data will introduce little error into the average exposure concentration in a network of 30 sites.

Defining the Required Reduction

5.22 The required Exposure Reduction (or level of ambition) could be applied in one of two ways:

- to each monitoring site;
- to the average of all monitoring sites.

5.23 The application of the required reduction to each individual monitoring site has the advantage that the control strategy has to be applied to each urban area, and cannot be focussed on a few urban areas to the exclusion of others. However, there are several disadvantages:

[17] This would be done on the basis of the ratio of the site to the average of the other sites in year x being applied to the average of the other sites in the missing year.

- if a new development takes place in the general area of one monitoring station, then it may be impossible to achieve the required reduction, and the Member State would be in breach of the Directive;

- if the recommended option to remove rural background is adopted, then a separate rural background would need to be defined for each urban monitoring station, which would not be straightforward. There could even be situations where, for reasons of monitoring uncertainty and rural background uncertainty, the urban exposure increment could be negative;

- the use of one site makes the outcome more sensitive to the measurement uncertainty for the particular monitoring site, e.g. if the target reduction is 20 % over 10 years, and in the base year the monitor is, by chance, under-reading slightly by 3% and in the compliance year it is over-reading by 2%[18], then a 'true' reduction of 20% might only show as a reduction of 15%, and thus the site would be out of compliance.

5.24 A further potential disadvantage is that the required Exposure-Reduction could be achieved by a large reduction in PM concentrations at a small number of monitoring stations, with little or no reduction at the others. This would not accurately represent the reduction in PM exposure to the population. In practice however, provided that a sufficient number of monitoring stations are included (see para 5.7) this would be unlikely to occur. A more detailed analysis is provided in Appendix 8.

5.25 It is thus **suggested that the Exposure-Reduction approach is applied to the average exposure concentration across all monitoring sites.**

5.26 The required reduction could be expressed as a fixed concentration reduction in $\mu g/m^3$ or as a percentage. The advantages and disadvantages of these two options are set out in Table 8.

[18] In practice, the under- and over-reading of the instrument would be unknown, as it would be within the uncertainty of the instrument.

Table 8 Comparison of Advantages and Disadvantages of a Fixed Reduction Compared to a Percentage Reduction.

<table>
<tr><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td colspan="2">Fixed reduction (μg/m³)
The same absolute improvement in health would apply to each Member State, i.e. in principle if there are 10 million people exposed, then each Member State would reduce the number of death / hospital admissions by the same amount.</td></tr>
<tr><td></td><td>A 1 μg/m³ reduction will be harder to achieve in a country that has relatively low exposure than in a country that already has high concentrations (UB-R). Thus the effort required to meet the reduction will not be equitable.</td></tr>
<tr><td colspan="2">Percentage Reduction
An improvement in health proportional to the excess above the rural background would apply to each Member State.</td></tr>
<tr><td>Member States with the highest concentrations (UB-R) would experience the greatest reductions in the number of deaths / hospital admissions. This would seem to be more equitable.
It is likely to be easier to achieve a prescribed percentage reduction than an absolute reduction.</td><td></td></tr>
</table>

5.27 It is **suggested that the reductions required by Member States would be best determined using the modelling procedures developed by IIASA to support the Commission's CAFÉ programme**. The IIASA model is already best suited to determining exposures, and is not suited to determining concentrations at hot-spots as required for the determination of Limit Values. The IIASA approach, assuming secondary pollutants are not incorporated in the exposure definition (by subtraction of the rural background), would require the modelling and cost effectiveness studies to be based on changes to the primary component of PM emissions alone (the modelling and optimisation of secondary PM reduction would be carried out under the review of the NEC Directive). There would be the opportunity using this modelling to give different exposure-reduction values to each Member State. This may though be overly complicated.

5.28 The **suggested approach is to apply the same percentage Exposure-Reduction value to all Member States.** It is possible to envisage a de-minimus concentration reduction in μg/m³ below which the Exposure-Reduction approach would not apply to a Member State, as it would essentially be unmeasureable. For instance, if a 20% reduction was required and this equated to an average exposure reduction of less than 0.5 μg/m³, then it may be more appropriate to rely solely on Limit Values and the National Emission Ceiling for this Member State.

Base Year

5.29 A further issue that requires consideration is the definition of a base year, from which the Exposure Reductions will run. If the new approach is to be applied to $PM_{2.5}$, then the base year will need to be defined by the network of monitoring stations that would be established following implementation of the Directive introducing the new approach. The base year is thus unlikely to be earlier than 2008 or 2009[19]. If the new approach is applied to PM_{10}, it is unlikely that every Member State would have the appropriate network of monitoring stations as part of the current Directive, and thus the new approach would still have a similar base year.

5.30 The date by which the required reduction is to be achieved would need to be some years after introduction of the new Directive. It is suggested that a realistic time-scale would be 10 years from implementation of the Directive. This timescale is in line with current thinking on new Limit Values, as part of the CAFÉ programme.

Compliance Checking

5.31 Compliance checking would be straightforward using the monitoring data. The annual Exposure concentration for a Member State would be compared against the Base Year Exposure concentration. It is not considered appropriate to use modelling to check compliance, as this would suffer the problems of the modelling approach outlined as option B1 in section 4. Consideration does though need to be given to the variability in meteorology, which can influence concentrations. This is particularly acute if one-year concentrations are used. There is a risk that the base year is a high or low pollution year due to meteorological conditions and that the same will apply to the compliance year and subsequent year. This is illustrated in the annual data for sites in the UK in Figure 10.

5.32 One way around this problem is to define compliance on the basis of a running-average concentration. Figure 10 illustrates the effect of averaging annual mean PM_{10} from 7 sites over a range of years, up to 5. The greater the number of years included in the average the less a particular year influences the concentrations. This is even more evident when the rural background is subtracted as shown in Figure 11, providing further justification for subtraction of the background. The smoothest pattern is shown for 5-year averages, but for practical reasons the shortest averaging period should be sought. Examination of the results in Figures 10 and 11 **suggests that a 3-year rolling average, updated on an annual basis would provide an appropriate measure of exposure**.

[19] If, as suggested in the Compliance Checking section, a 3-year running average is applied, then the base year would actually be the average of 3 years, 2008-2010 or 2009-2011.

6 Conclusions

6.1 Various options for introducing an Exposure-Reduction approach, based on monitoring, for the control of PM, have been considered from a practical standpoint. These range from relatively simple options, based on average concentrations measured at a selected number of monitoring stations in each Member State, to more sophisticated approaches involving explicit population weighting, and the subtraction of proportions of the rural background component.

6.2 From the point of view of implementation across 25 Member States, the simpler approaches are more attractive. This would require the establishment of suitable urban background monitoring stations within each Member State, and would largely complement requirements under existing, or likely future Directives. Nonetheless, issues regarding site types raised in Section 5 are considered to be critical, and a more formal classification of monitoring sites across Europe is suggested.

6.3 Account has been taken of the recent proposals being considered by the Commission to adopt structural indicators for PM_{10} based on population-weighted exposure, using the current monitoring network being reported to the Commission by Member States. In the event that this approach is adopted, then a similar method could be used to define exposure for the Exposure-Reduction approach. This would provide a harmonised approach, although the structural indicators, as currently defined, are not such a robust measure of exposure as might be required for an Exposure-Reduction approach.

6.4 From a scientific point of view, and for the purpose of setting equitable Exposure-Reduction targets or levels of ambition across Member States, an approach that includes the subtraction of the rural background is preferred. Whilst more complex to implement, this would provide a system that would better reflect the effort required by the Member State to achieve the ambition level, and would be more understandable to the public. The required increase in rural monitoring would provide invaluable information to improve understanding of PM. In the event that subtraction of rural background measurements is not included in an Exposure-Reduction approach, then information on the expected change in background PM levels (derived from IIASA or EMEP) could be used to assist in setting the required Exposure-Reduction.

6.5 It is envisaged that the Exposure-Reductions required to be achieved by each Member State would be determined using the modelling procedures developed by IIASA to support the Commission's CAFÉ programme. This exercise may be best run in parallel with the work being carried out to revise the First Daughter Directive and the NECD. It is envisaged that in the first instance, the required Exposure Reduction would be expressed as a single percentage reduction to be achieved by all Member States by a specified date.

Other Matters

6.6 Some consideration of timescales for implementation has already been provided in Section 5. Ideally, an Exposure-Reduction approach would be introduced at the time of the revision of the First Daughter Directive. This would allow both Limit Values and Exposure-Reduction targets to be developed alongside each other. However, the timescale for revision of the Directive may preclude this from happening.

6.7 An alternative mechanism for implementation would be to consider the Exposure-Reduction approach alongside the revision to the NECD. The way in which National Emissions Ceilings and Exposure-Reduction targets would complement each other has been discussed in previous sections of this document. It is suggested that in these circumstances, the CAFÉ Thematic Strategy highlights the requirement for an Exposure-Reduction approach, which would be considered during the review of the NECD.

6.8 The question also arises as to whether the approach should be applied regionally for Member States with a strong regional Government structure, e.g. Germany and Spain? It is considered that this is a matter that should be left up to each Member State to decide. If a Member State wishes to devolve down responsibility to regional Government then it can clearly choose to do so, but the Member State would still be responsible for meeting the required Exposure Reduction, as determined by averaging across all the selected monitoring sites within all the regions within that Member State.

6.9 There may be local developments being undertaken for reasons of regional economic development, which could mean that certain areas may experience an increase in PM concentrations. The proposed approach recognises this, but in these circumstances, the Member State would need to ensure greater reductions elsewhere to compensate for any increase, to ensure that the required Emission Reduction is met. The Limit Value approach will ensure that any local increases due to development are not excessive.

6.10 Consideration has been given to the terminology for the new approach. This is summarised in Appendix 9.

References

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

EC (2004) Second Position Paper on Particulate Matter, CAFÉ Working Group on Particulate Matter, European Commission.

WHO (2003) Air Quality Guidelines for Europe, Second Edition, WHO Regional Publications, European Series, No. 91

Figure 1 Focus of Controls for Different Approaches to Limit Exposure of People to PM

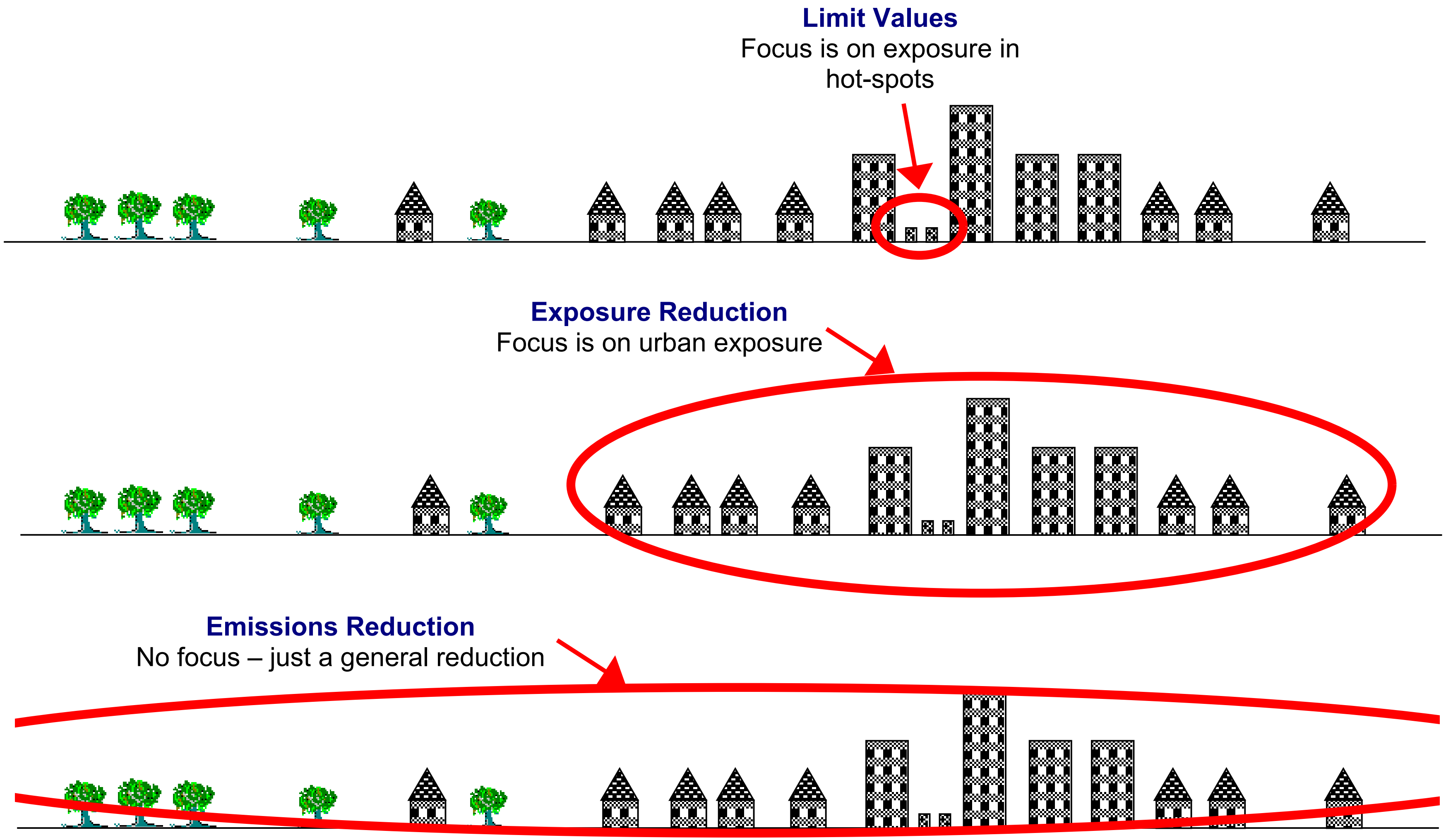
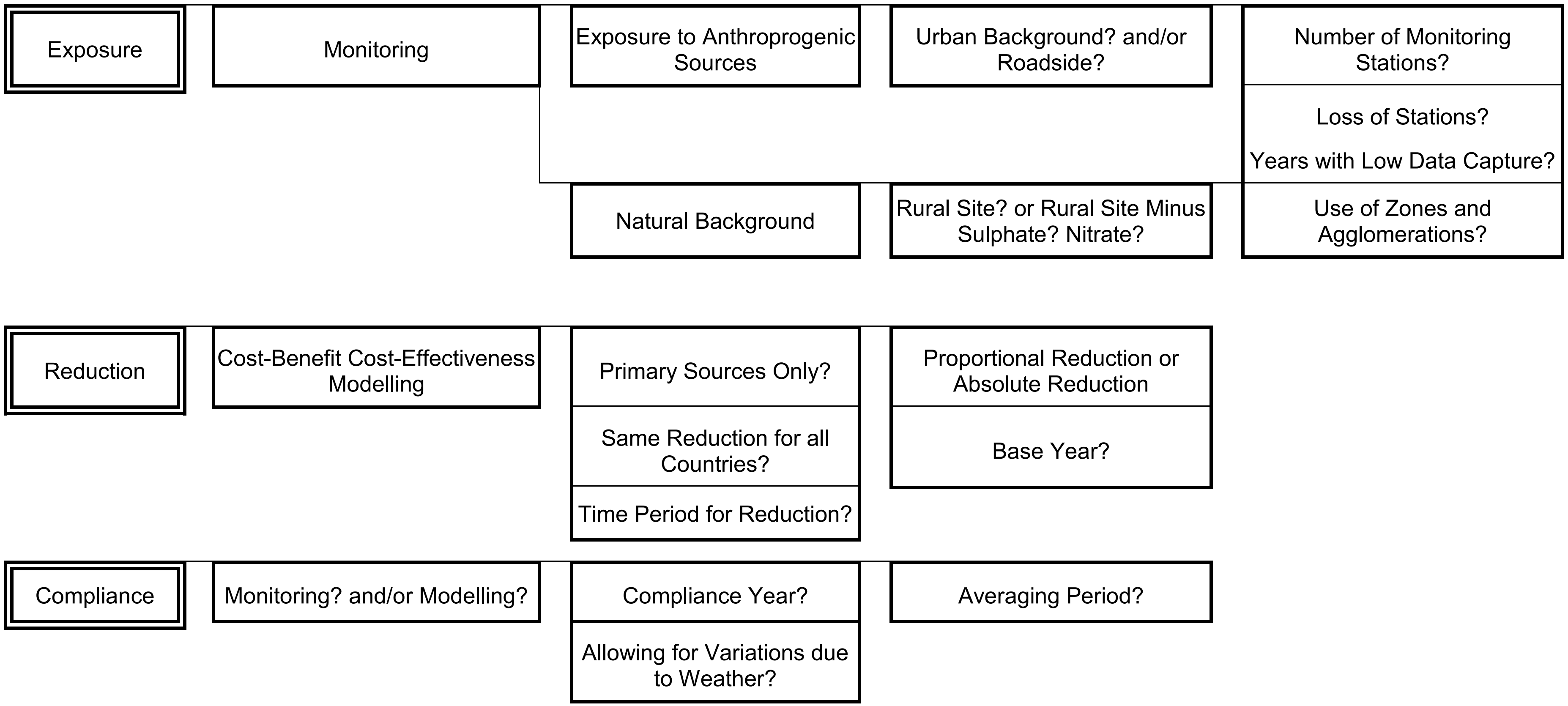


Figure 2 Issues for Exposure Reduction Approach



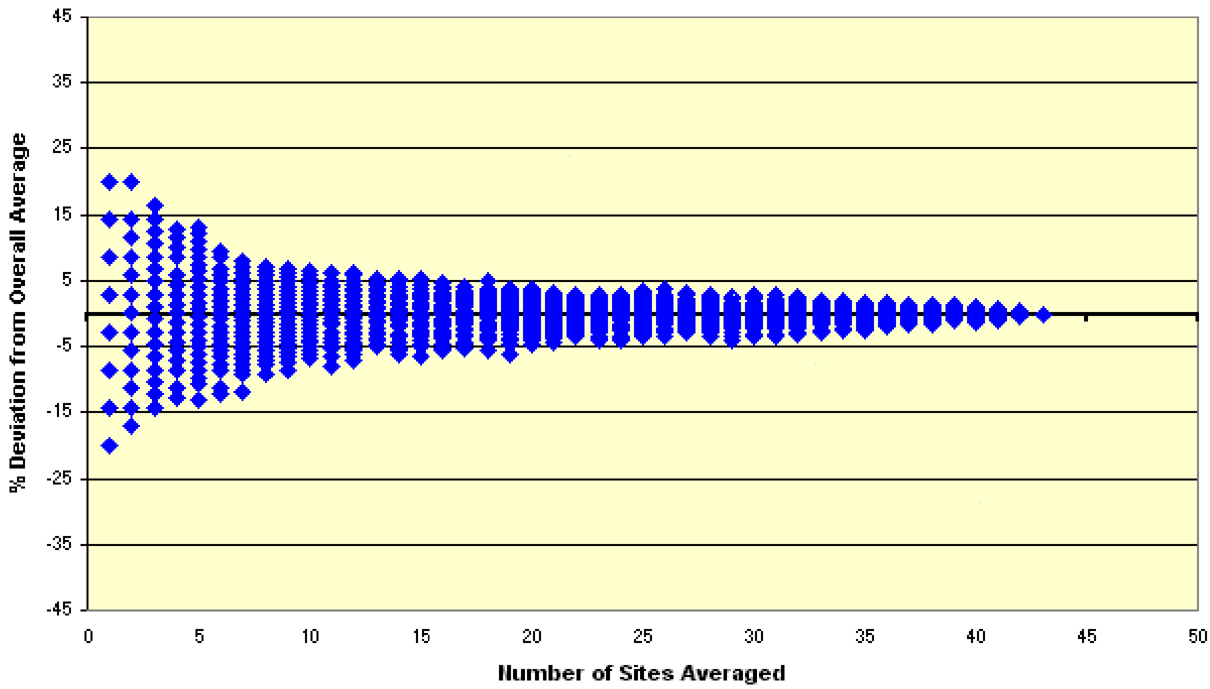


Figure 3 Deviation from Overall Average PM10 for UK Urban Background, Suburban and Urban Centre Sites in 2002.

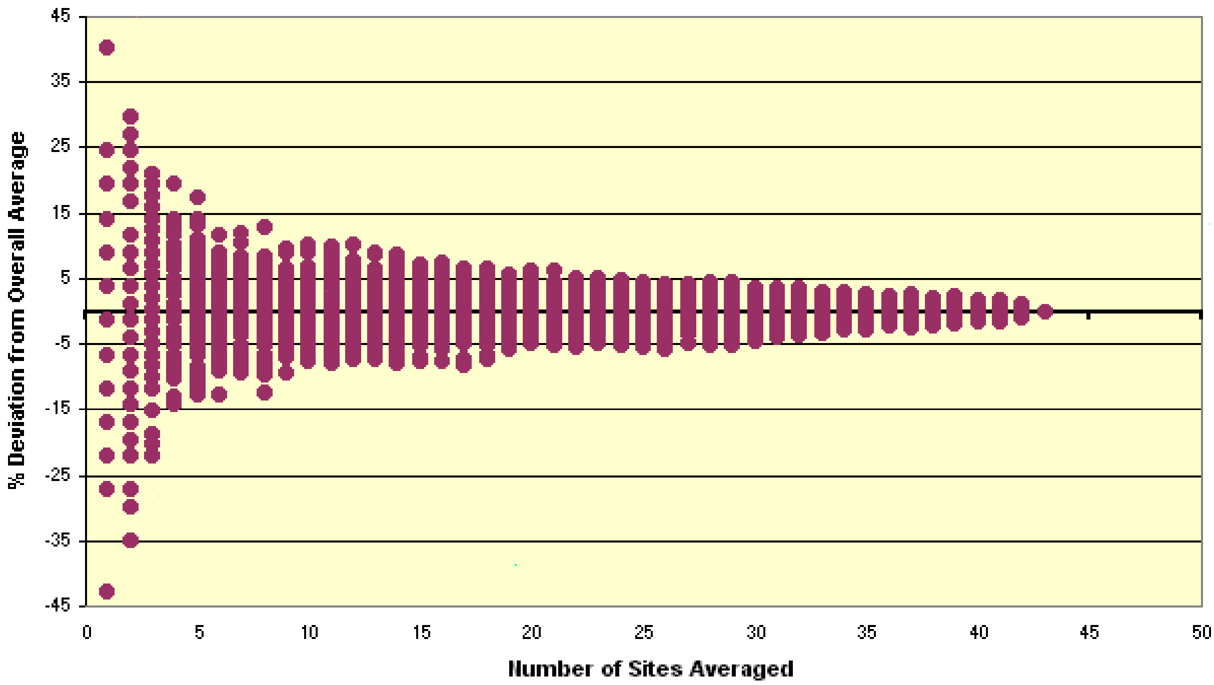


Figure 4 Deviation from Overall Average PM_{10} for UK Urban Background, Suburban and Urban Centre Sites in 2003.

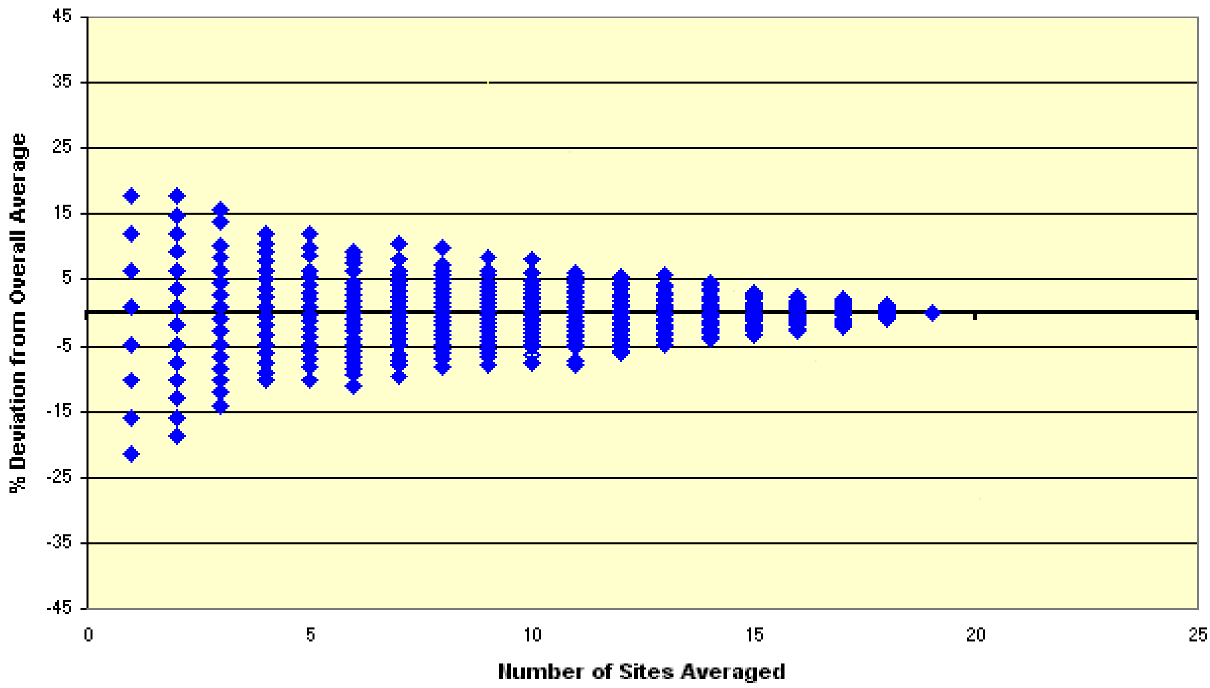


Figure 5 Deviation from Overall Average PM_{10} for UK Urban Centre Sites in 2002.

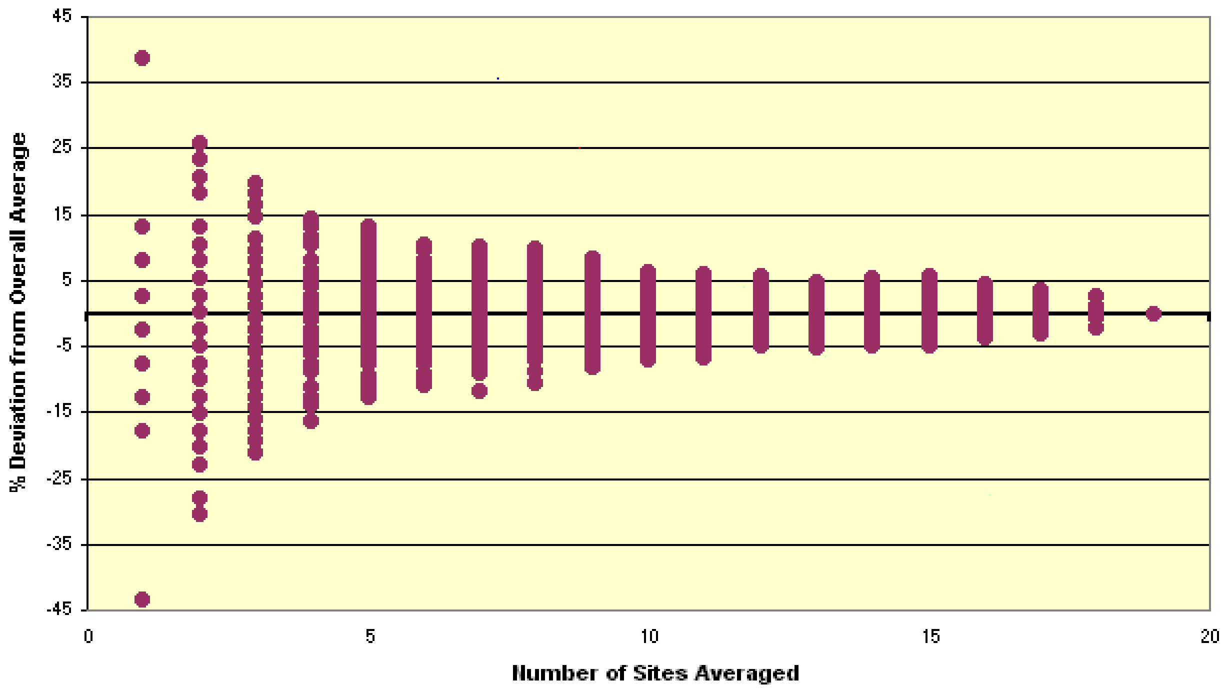


Figure 6 Deviation from Overall Average PM_{10} for UK Urban Centre Sites in 2003.

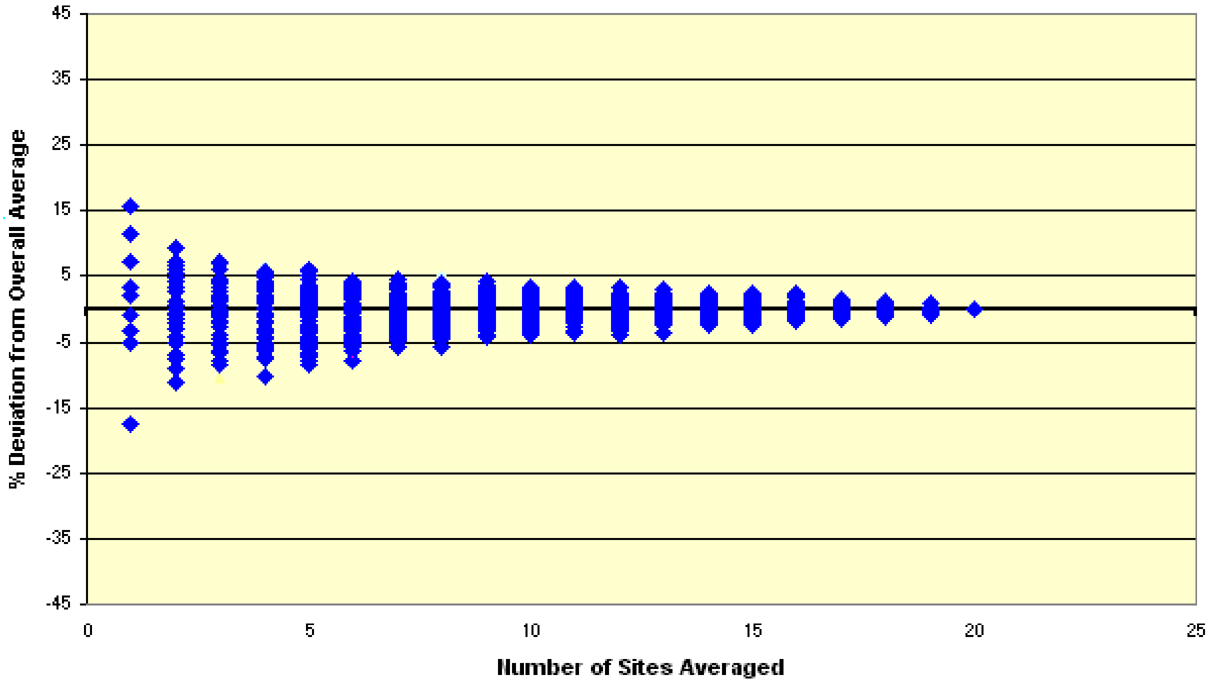


Figure 7 **Deviation from Overall Average PM_{10} for London Urban Background and Suburban Sites in 2002.**

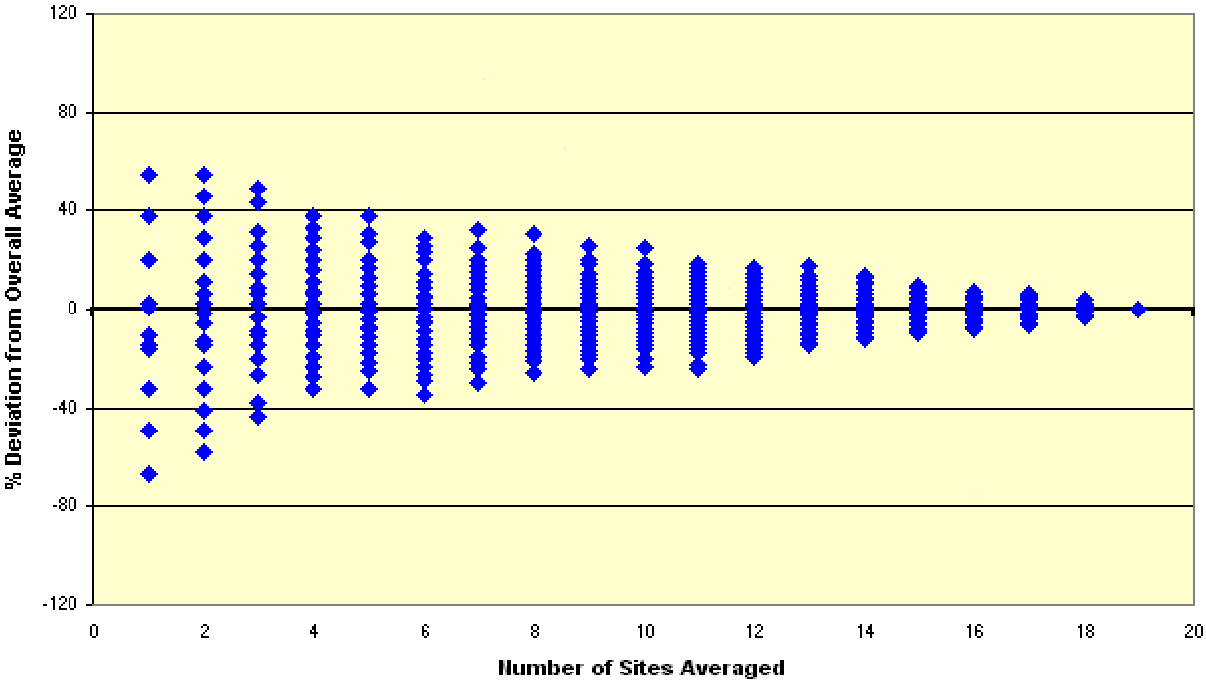


Figure 8 **Deviation from Overall Average PM_{10} for UK Urban Centre Sites Minus UK Rural Background in 2002.**

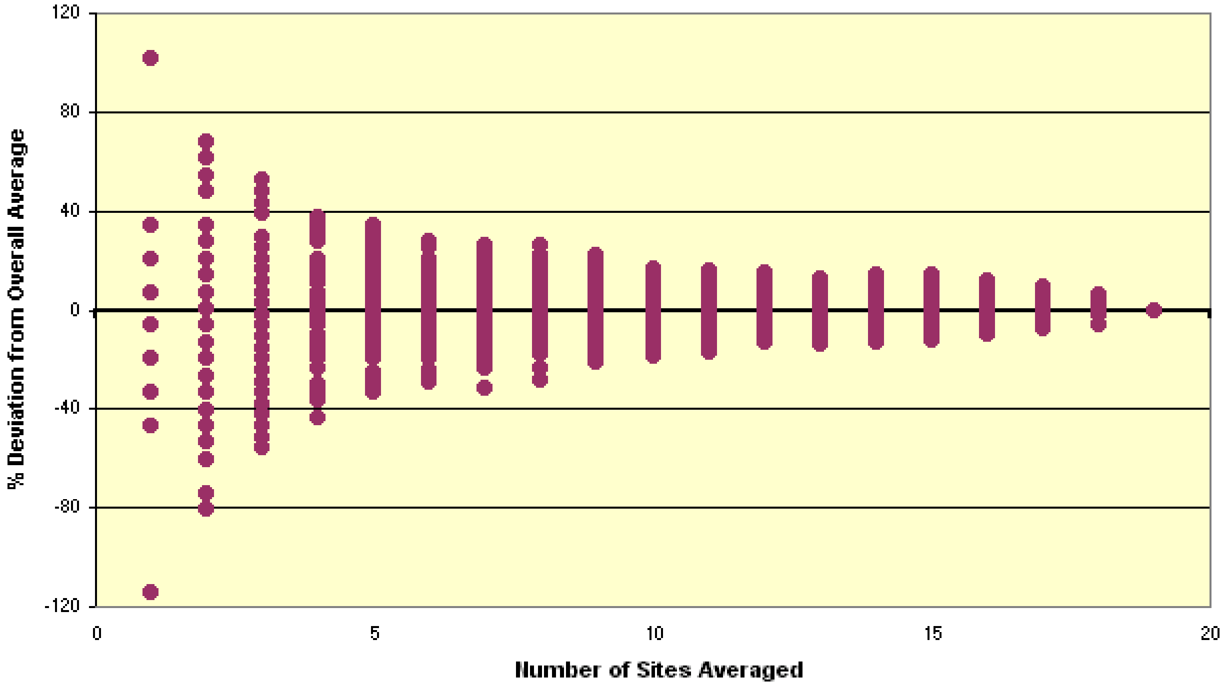


Figure 9 Deviation from Overall Average PM_{10} for UK Urban Centre Sites Minus UK Rural Background in 2003.

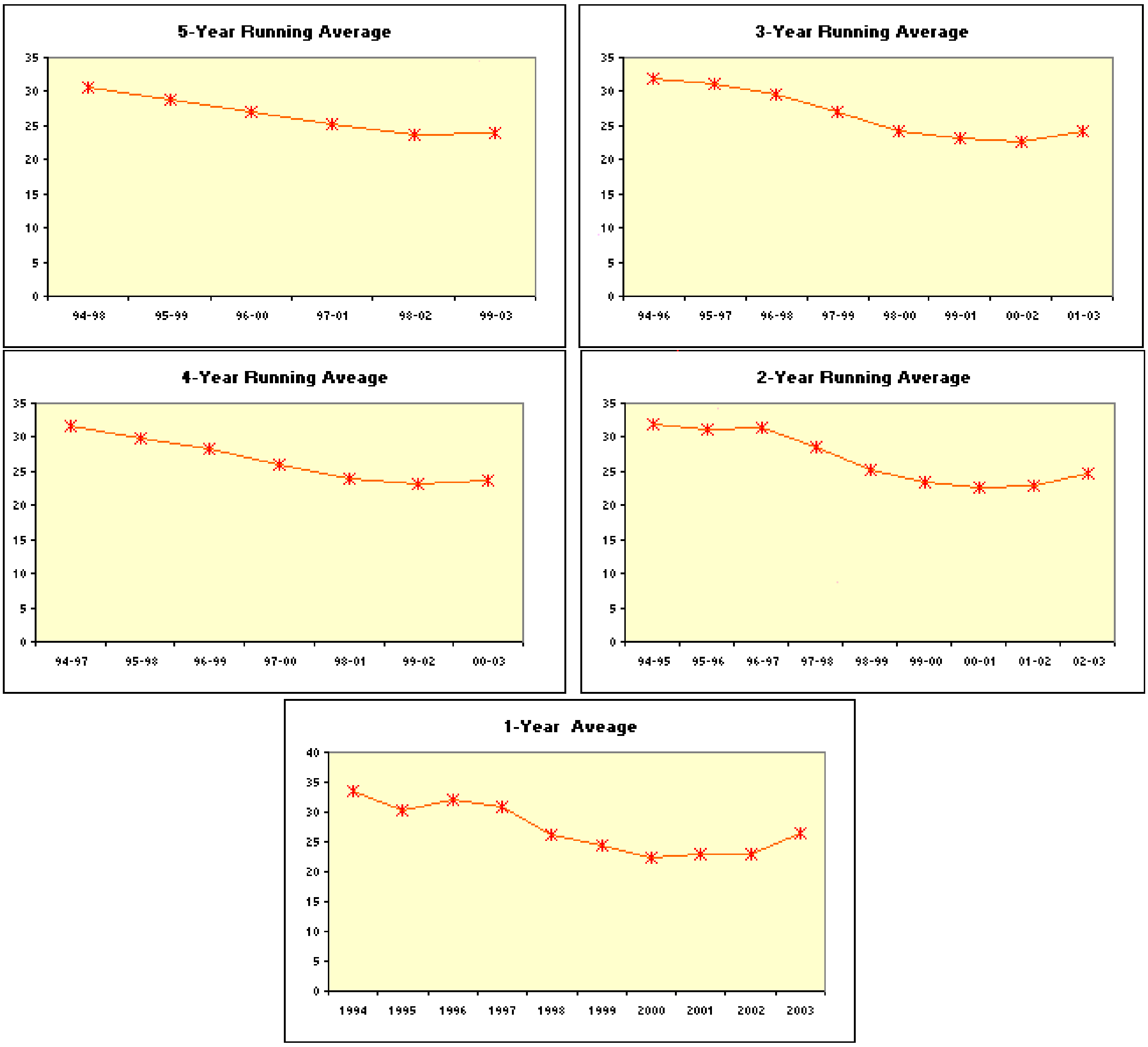


Figure 10 PM_{10} concentrations for 7 sites in UK (Leicester, Newcastle, Belfast, Bristol, Cardiff, Birmingham, Leeds), 1994-2003 for different averaging periods.

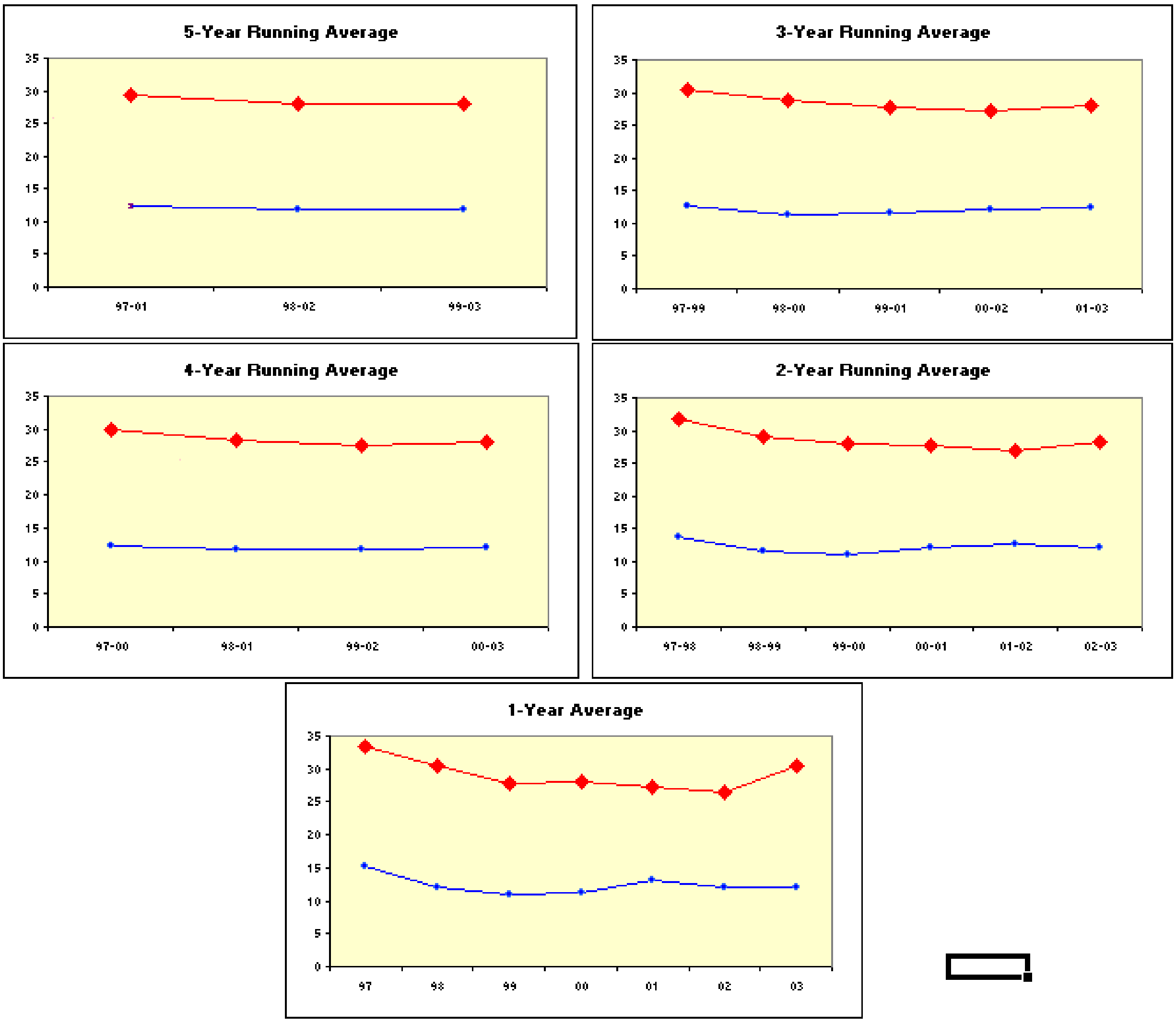


Figure 11 **PM_{10} concentrations for 3 sites in Wales (Port Talbot, Cardiff, Swansea). Top (red) line is average over different running average periods. Bottom (blue) line is average minus the rural background (Narbeth).**

Appendix 1

Extract from Report "Second Position Paper on Particulate Matter" by the CAFÉ Working Group on Particulate Matter.
Section 11.3, Pages 178-179

Thus, while it is recognised that limit values have an important role to play in helping drive down exposure, the Working Group recommends that the Commission consider the use of alternative approaches, such as gap closure, emissions ceilings or targets, to supplement (but not replace) the use of limit values.

The Working Group has not given detailed consideration to the gap closure or target approach, but some initial ideas and principles are worth setting out as an example. The objective of this approach would be to reduce *total population exposure*, thereby maximising the public health benefits of actions to improve air quality. It would rely on the progressive closure of the gap between the *natural background* concentration and the *current population weighted exposure*. For example, the gap closure approach could be operated on the basis of monitoring and/or modelling of annual mean concentration values, or it could be used to develop emission reduction targets, so as to parallel the National Emissions Ceiling (NEC) Directive approach. It would be consistent with the approach to cost/benefit analyses being carried out as part of the integrated assessment procedure for ambient PM.

The population-weighted average PM concentration for a Member State would be strongly influenced by concentrations in urban areas, especially the larger urban areas. The background average concentration for an urban area could be determined either by modelling (validated against measurement) or by measurement. The requirement would be to consider all 'agglomerations' in the calculation of the population-weighted average. The contribution of exposure outside of urban areas could either be left out of the equation, or based on measured rural background concentrations at an agreed number of sites or on modelling of the rural background. The 'natural' background could be determined by monitoring, coupled with source apportionment.

Appendix 2

Extract from Air Quality Expert Group Report on "Particulate Matter in the United Kingdom" Section 9.14.

9.14 What are the differences between strategies that address hotspots of exceedence and those that aim to reduce population exposure? Should policy evaluation consider impacts on population exposure, as well as concentrations at specific locations?

Answer

902. Strategies based solely on limit values tend to focus attention on reducing concentrations in localised areas or 'hotspots' where exceedences are measured or predicted. However, such localised areas are unlikely to be associated with large population exposure. For pollutants such as PM, where there is no evidence of a threshold concentration below which health effects do not occur, a strategy based on reducing exposure to the largest population would seem to offer improved benefits to public health. The Expert Group recommends further work on developing such a strategy.

Rationale

903. Air quality control is currently based upon the use of limit values that are defined in the Air Quality Daughter Directives. Limit values have proved to be an extremely useful mechanism over the past 20 years or so; they provide a simple, uniform measure of progress in improving air quality, as well as providing a driver for emissions controls, and helping raise public awareness. There are however emerging limitations with this approach.

904. The limit values for human health apply to all locations within a Member State, and this inevitably leads policy makers towards the improvement of conditions in areas of very poor air quality, i.e. hot spots, where the limit values are exceeded. For particulate matter, these hot spots will include major roads, particularly within urban centres in the majority of European cities. If there are no exceedences of the limit values, then the Member State will not be required to develop any policy measures to further reduce exposure to particulate matter.

905. However, it is widely recognised that in the case of particulate matter, there is no threshold concentration below which there are no health effects. It may be concluded that any reduction in exposure would be associated with an improvement to health, even if levels are below the limit value. In terms of maximising health benefits to the general population, such an approach is expected to be far more effective, e.g. reducing the exposure of 10 million people by 0.1 $\mu g/m^3$ is ten times more effective than reducing the exposure of 1,000 people (at hot spots) by 10 $\mu g/m^3$.

906. A system of control, in addition to limit values, and based on reducing the long-term population-weighted exposure is suggested. Within this strategy, the aim is to reduce particulate matter concentrations, expressed as a population-weighted average, over individual zones and agglomerations, or across the country as a whole.

Appendix 3

Interim Environmental Targets Underlying the National Emissions Ceiling Directive

Acidification. The areas where critical loads are exceeded shall be reduced by at least 50 per cent in all areas as compared with the situation in 1990.

Health-related ozone exposure. Ground-level ozone above the critical level for health shall be reduced by two-thirds in all areas compared with the situation in 1990. Moreover the ground-level ozone load shall not exceed a given absolute limit anywhere.

Vegetation-related ozone exposure. Ground-level ozone above the critical level for vegetation shall be reduced by one-third in all areas compared with the situation in 1990. In addition, the load shall not exceed a given absolute limit anywhere.

Appendix 4

National Emissions Ceiling Directive Review

An Inception Report prepared by Entec UL Limited sets out the scope of work to address the feasibility of introducing and emissions ceiling for primary PM. The questions that will be addressed are as follows:

1. What are the limitations of current EU approaches to reducing exposure to particulate matter? How much do secondary and primary components of anthropogenic origin contribute to concentrations, and how is this likely to change with current legislation?

2. What are the appropriate geographical scales for control – e.g. to what extent is primary particulate matter a transboundary/local problem?

3. How much do different anthropogenic sources contribute to emissions; how significant are they in health terms and how well can they be quantified for reliable emissions inventories and estimation of abatement potential? What are the characteristics of these source components in terms of:

    - Source type (e.g. point, elevated or ground level, diffuse, area, fugitive sources);
    - Particle size distribution;
    - Particle composition/chemical speciation;
    - Relative health impact;
    - Uncertainty of abatement measures.

4. How can emissions ceilings be decided and for what components? Can integrated assessment or gap closure methods be extended to primary particulate matter, or are there other ways of selecting what emissions ceilings are appropriate? Are emissions ceilings measurable and efficient in terms of effects?

5. What are the issues for implementation and compliance, and how do these compare with other approaches?

6. What are the pros and cons of the various options for introducing emissions ceilings for particulate matter?

Appendix 5

Proposed Method for the Calculation of Structural Indicators for PM_{10} based on Population-Weighted Exposure

$$SI_{PM} = \frac{\sum_i C_i \times Pop_i}{\sum_i Pop_i}$$

, sum over urban and suburban background monitoring stations within the country, where

SI_{PM} Structural Indicator for urban population exposure to PM (average concentration)

Pop_i Population in the representative area around i-th station

C_i 3.0 Annual average PM_{10} concentration, monitored on the i-th urban or suburban background station

Detailed description and further requirements

Population attributed to the station is calculated from the disaggregated grid 100x100m as people living within 3km of the monitoring station. Where areas of representativeness intersect, a procedure is applied to attribute population to the closer station, thus preventing it to be counted twice.

The following requirements are put on the selection of stations and data to assure the comparability:

– only the (sub)urban background stations used for compliance checking under the 1999/30/EC are to be used, unless this imposes too serious restriction on the set. In that case, further QA/QC investigation is made to assure compatibility with the 1999/30/EC Data Quality Objectives, as well as to get assurance on the stability of operation.

– For each measurement data, a measurement method has to be known. If a non-reference method (TEOM, beta-gauge instead of gravimetric according to EN12341) has been used, a potential correction factor to assure equivalency with the reference method has to be applied appropriately. The factor may change in time, but a process has to be put in place to assure that changes are due to proper reiteration of equivalence testing and not administrative arrangements. If this is assured, a measurement uncertainty (including non-ideally corrected bias) will not exceed 25 %.

- Complementary information has to be provided on the country level and the metrics completeness (population fraction covered per country, number of stations) and be clearly displayed with the indicator.

Appendix 6

Summary of PM_{10} Monitoring Sites in Europe (source AIRBASE database)

	Number of Monitoring Stations		
Country	**Rural Background**	**Suburban Background**	**Urban Background**
AUSTRIA	14	15	11
BELGIUM	1	9	6
BULGARIA	0	8	12
CZECH REPUBLIC	20	9	21
DENMARK	2	0	3
ESTONIA	0	0	1
FINLAND	1	3	3
FRANCE	10	72	119
GERMANY	76	83	118
GREECE	0	4	0
HUNGARY	0	0	0
ICELAND	0	0	1
IRELAND	0	4	1
ITALY	9	35	54
LITHUANIA	0	0	3
MACEDONIA	0	1	0
NETHERLANDS	11	1	4
NORWAY	0	0	4
POLAND	4	0	26
PORTUGAL	1	4	6
SLOVAKIA	0	1	15
SLOVENIA	0	1	3
SPAIN	22	14	47
SWEDEN	0	0	4
SWITZERLAND	6	4	4
UNITED KINGDOM	3	5	47

Note: Sites classified as Industrial or Traffic have been excluded from this analysis. Urban background stations in both France and Spain include sites categorised as 'unknown background'.

Appendix 7

Summary of Sulphate and Nitrate Monitoring Stations in Europe (source AIRBASE database)

Country	Number of Monitoring Stations	
	Sulphate	Nitrate
AUSTRIA	0	0
BELGIUM	5	0
BULGARIA	0	0
CZECH REPUBLIC	0	0
DENMARK	8	6
ESTONIA	1	0
FINLAND	6	0
FRANCE	9	0
GERMANY	11	6
GREECE	0	0
HUNGARY	3	3
ICELAND	0	0
IRELAND	0	0
ITALY	0	0
LATVIA	2	2
LITHUANIA	0	0
MACEDONIA	0	0
NETHERLANDS	7	7
NORWAY	10	0
POLAND	0	0
PORTUGAL	1	0
SLOVAKIA	0	0
SLOVENIA	0	0
SPAIN	0	0
SWEDEN	7	0
SWITZERLAND	0	0
UNITED KINGDOM	0	0

Appendix 8

Assessment of Reduction Scenarios at Individual Sites on the Calculated Annual Mean

An Exposure-Reduction approach based on the average exposure concentration across all sites represents a much simpler approach than one based on individual sites. This approach does however require that there would be a broadly consistent reduction in PM concentrations across all monitoring sites. There is the potential that the Exposure-Reduction target could be achieved by a very large reduction at a single, or very few sites, with no reduction at others. This would then not accurately represent exposure reduction to the population.

An assessment of the likelihood of this occurring has been carried, based on urban and suburban monitoring stations within the UK network for 2002 (a total of 43 sites). As a base case a 5% reduction in average PM_{10} concentrations was assumed. Two scenarios were considered:

- A single site was selected at random. Concentrations at all other sites were then assumed to reduce by progressively 1, 2, 3 and then 4%, and the required reduction at the single selected site calculated, such that the overall reduction would be 5%. Even assuming a 4% reduction at all other sites, the necessary reduction at the single site would be 39% in order to reach the overall 5% target

- A 20% reduction was applied to an increasing number of sites selected at random, with concentrations at all other sites remaining unchanged. It was necessary to apply a 20% reduction to 10 sites (almost a quarter of the total) to achieve the required overall 5% reduction.

It may be concluded that given a sufficiently large number of sites, the average concentration is not significantly influenced by even large changes to a small number of the monitoring locations.

Appendix 9

Terminology

The new approach has been widely referred to as a gap-closure approach. While this term explains the essence of what is to be achieved, it suffers from being confused with the terminology associated with the National Emission Ceilings (NEC) Directive and the concept of critical loads. In this context the gap to be closed is that between existing pollutant load to a sensitive ecosystem and the critical load (i.e. threshold) for that ecosystem. The NEC Directive uses the critical load concept to derive emission reduction targets necessary to achieve the required gap-closure. The control and associated compliance checking is through emission inventories. This differs fundamentally from the proposed new approach for controlling pollutants causing health impacts, where there is no evidence of a threshold for effect, which is based on control and compliance checking through exposure concentrations.

In these circumstances, it is thought to be helpful to use a completely new terminology. The following list shows options considered, each group being a variant on a theme.

Exposure target (ET)
Exposure limit value (ELV)
Exposure reduction (ER)
Exposure reduction value (ERV)
Exposure reduction limit value (ERLV)
Exposure reduction target (ERT)

Exposure concentration target (ECT)
Exposure concentration limit value (ECLV)
Exposure concentration reduction (ECR)
Exposure concentration reduction value (ECRV)
Exposure concentration reduction target (ECRT)

Exposure-based target (E-B T)
Exposure-based limit value (E-B LV)
Exposure-based reduction (E-B R)
Exposure-based reduction value (E-B RV)
Exposure-based reduction target (E-B RT)

The use of the words 'target' and 'limit value' are considered to be potentially confusing as these words are used in current Directives. The phrases with the word 'concentration' included are thought to be too long.

The preferred option for an exposure approach without direct population weighting is **Exposure Reduction.** Thus a Directive will set an Exposure Reduction to be achieved by member states, while the whole concept is an Exposure-Reduction approach.