AIR QUALITY EXPERT GROUP

Nitrogen Dioxide in the United Kingdom

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

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AQEG reports to the Secretary of State for Environment, Food and Rural Affairs, Scottish Ministers, the National Assembly for Wales and the Department of the Environment in Northern Ireland (the Government and Devolved Administrations). AQEG is an advisory non-departmental public body in England, Wales and Northern Ireland. In terms of the Scotland Act 1998, the Group is a jointly established body.

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- to give advice to ministers on levels, sources and characteristics of air pollutants in the UK;
- to assess the extent of exceedences of Air Quality Strategy objectives and proposed objectives, EU limit values and proposed or possible limit values, where monitoring data is not available;
- to analyse trends in pollutant concentrations;
- to assess current and future ambient concentrations of air pollutants in the UK; and
- to suggest potential priority areas for future research aimed at providing a better understanding of the issues that need to be addressed in setting air quality objectives.

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Executive summary

This report provides a detailed analysis of nitrogen dioxide in the UK. It addresses:

- Emissions sources and their past and projected trends.
- Meteorological and chemical processes that affect ambient nitrogen dioxide concentrations.
- Measurement methods and networks.
- Modelling and mapping methods and their coupling with measurements at monitoring sites to predict future concentrations of nitrogen dioxide.
- Analysis of monitoring data and projections of future concentrations and likely exceedences of air quality objectives and limit values.

This report will not address health effects, indoor air pollution or effects on ecosystems or vegetation. The later was dealt with in the National Expert Group on Transboundary Air Pollution (NEGTAP) Report on Transboundary Air Pollution: Acidification, Eutrophication and Ground-Level Ozone in the UK, published in 2001.

EU Limit values and Air Quality Strategy Objectives for nitrogen dioxide (NO_2) are shown in the table below. They are primarily based on health effects. At relatively high concentrations, NO_2 causes inflammation of the airways. There is evidence to show that long-term exposure to NO_2 may affect lung function and that exposure to NO_2 enhances the response to allergens in sensitised individuals. The effects of NO_2 are related to the total exposure to the pollutant over the relevant averaging period, both the 1-hour and annual periods. This exposure will take place in a whole range of micro-environments, each with its own concentration pattern. UK objectives only apply where there is exposure (or likely future exposure) that relates to the relevant averaging period. For instance, for the annual mean NO_2 objective the relevant roadside location is the façade of a residential building, while for the 1-hour objective it would be the pavement of a street where people might regularly spend up to an hour, for instance a street with pavement cafes.

Legislation	Hourly (µg m^{-3}) objective	Annual (µg m^{-3})	Achieve by
EU First Daughter Directive (99/30/EC)	200 µg m^{-3} with up to 18 exceedences per year	40	2010
Air Quality Strategy (2000)	200 µg m^{-3} with up to 18 exceedences per year	40	2005

In addition, NO_2 contributes to the formation of ozone (O_3) and of secondary particles and is implicated in acidification and eutrophication. The National Emission Ceilings Directive establishes a national limit for each Member State for emissions of nitrogen oxides (NO_x) and other atmospheric pollutants. It incorporates (and in some cases goes beyond) ceilings established earlier under the *UNECE Convention on Long-Range Transboundary Air Pollution Gothenburg Protocol*. Under the Directive, the UK is committed to reducing its national annual emission of NO_x from 1728 kt as NO_2 in 2000 to below 1167 kt as NO_2 by 2010.

Emissions

- All combustion processes in air produce NO_x. NO_2 and nitric oxide (NO) are both oxides of nitrogen and together are referred to as NO_x. It is NO_2 which is subject to health based air quality standards.
- Overall emissions of NO_x have fallen by 37% from 2744 kt as NO_2 in 1990 to 1728 kt as NO_2 in 2000 due mainly to reductions in emissions from road transport and public power generation.
- Road transport is the largest source of NO_x emissions in the UK, contributing 49% of total emissions in 2000. However, emissions from road transport have fallen by 34% between 1990 and 2000 following improvements in engine design and the fitting of three-way catalysts to petrol cars, as a result of increasingly tight European vehicle emission standards.
- The contribution of road transport to NO_x emissions in urban areas is generally higher than the national average. Thus, total urban UK (and London only) road transport emissions of NO_x in 2010 are predicted to have declined by 49% (and 53%) from 1999 levels, respectively.
- UK NO_x emissions from all sources are projected to fall by a further 25% from 2000 levels by 2010. This is largely driven by a continuing decline in emissions from road transport as vehicles meeting tighter emission standards penetrate the UK fleet.
- NO_x emissions are primarily in the form of NO, but there is evidence for significant amounts of NO_2 emitted directly from the tailpipe of diesel vehicles, especially when slow moving, with levels possibly as high as 25% of total NO_x emissions in mass terms. These primary emissions have a significant impact on roadside NO_2 concentrations in areas where there is considerable diesel vehicle activity. The effect of new exhaust after-treatment technologies on primary NO_2 emissions from diesel exhaust needs to be monitored, especially catalytically regenerating traps used to reduce particulate emissions.
- Current evidence suggests that increasing the diesel car penetration rate in the UK fleet would lead to a small increase in NO_x emissions from road traffic in urban areas, but a more significant increase in primary NO_2 emissions. An increase in diesel car sales in 2010 from 22% of new car sales (close to the current rate) to 30% could increase urban UK road transport emissions of NO_x in 2010 by 0.7% and NO_2 emissions by 3%.
- The contribution to annual mean NO_x concentrations in 2001 from domestic and commercial emissions (primarily natural gas space heating) at background locations in central London is estimated to be about a quarter. Emissions from these sectors are expected to increase somewhat over the next 10 years or so across the UK, in contrast to the decline of emissions from traffic.
- Uncertainties in national emission estimates need to be continuously re-evaluated. Current assessments suggest a ±7% uncertainty in total UK NO_x emission estimates for 2000 at the 95% confidence level. However, uncertainties of emissions from specific sources and their spatial distribution are much higher than this and need to be carefully considered in any inventories developed for local air quality modelling.

Meteorological and chemical processes

- The concentration of NO_2 at a given location is determined by a combination of emissions, meteorology and chemistry.
- In addition to primary emissions sources, secondary NO_2 is formed in a rapid chemical reaction between primary NO and O_3. The availability of O_3 close to the emission source is a key factor determining the concentration of NO_2. Source receptor relations differ for primary and secondary pollutants and the distinction between primary and secondary NO_2 is an important policy issue.
- Meteorological processes operating on scales from a few metres to hundreds of kilometres play an important role in controlling dispersion and accumulation of NO_2 and the availability of O_3.
- Very low wind speeds, temperature inversions and a shallow, stable boundary layer are necessary conditions for winter NO_2 episodes. Summer episodes of NO_2 are associated with ozone episodes, that is with hot, still, sunny days.

Measurements

- The chemiluminescent analyser is widely used for continuous monitoring of NO_2 concentrations in the UK. It is the reference method specified in the EU First Air Quality Daughter Directive and is based on the chemiluminescent reaction between NO and O_3.
- Monitoring of NO_2 concentrations using the chemiluminescent analyser is carried out on a national scale, on behalf of Defra and the Devolved Administrations, and at a regional or sector-specific scale, on behalf of local authorities, the Highways Agency, the power generation industries, and other organisations. These networks are subject to rigorous quality assurance and quality control procedures, which ensure the reliability of the data. This report draws heavily on data from these networks.
- No measurement is exact, and all ambient concentration data has a degree of uncertainty, which is quantified using information about the calibration and other quality assurance/quality control (QA/QC) procedures applied. All the data used in this report is expected to meet the uncertainty requirements currently being set out in detail for the purposes of European legislation. This uncertainty will generally be less than for emission estimates, which rely on imperfect knowledge of other factors as well as actual measurements of emissions.

Modelling and mapping

- Monitored data represent measurements that are made only at specific locations at specific times. As such, these data alone provide limited information about the spatial extent of pollutant concentrations and how pollutant concentrations may change in the future. Policy requirements therefore necessitate some form of modelling to be undertaken to address these limitations. Modelling methodologies can be categorised as (i) empirically-based statistical models and (ii) physical process-based deterministic models. Deterministic models are based on mathematical formulations which describe the physical and chemical processes operating within the atmosphere, and which can be expressed at different levels of complexity. Some models combine both approaches. All of these model types have been used in this report, especially in the interpretation of monitoring data and in the projection of future concentrations of NO_2.

- There are a number of uncertainties that should be taken into account in assessing the policy conclusions concerning NO_2 and NO_x based on empirical, dispersion and other physically-based process models. Emission estimates are a crucial source of uncertainty, particularly the mass fraction of NO_x emitted as NO_2 and the likely future split between vehicle-kilometres travelled by petrol and diesel cars. Difficulties remain in representing urban influences on dispersion of primary NO_2 and in representing the 3-dimensional distribution of O_3 in urban areas which drives secondary NO_2 formation. Extra uncertainties occur when estimating concentrations at roadside.

NO_2 concentrations and recent trends

- Measured NO_2 concentrations during 2001 have been assessed for a total of 212 automatic monitoring sites. Data from 15 of these sites have been analysed in detail in this report. Annual mean NO_2 concentrations above 40 µg m^{-3} (the annual mean objective for 2005 and limit value for 2010) were measured at the majority of roadside and kerbside sites in London and at about half of the background sites. Exceedences outside London were largely confined to roadside and kerbside monitoring sites. The measurements show that the annual mean is the key assessment objective for NO_2.
- Annual mean concentrations of NO_x at urban background and urban centre sites have declined over the past decade, with NO_2 showing a far more modest fall at most sites. An assessment of rolling annual mean concentrations at 11 background and roadside sites in London since 1996 shows a decrease in NO_x concentrations to 70% of the 1996 values. NO_2 concentrations in 2001 were 88% of their 1996 values. These trends can be reconciled with the changes in emissions by a combination of the source apportionment of current measured concentrations and the trends in emissions in published emission inventories.
- An analysis of the roadside NO_2 concentrations has shown the key role of the emissions of primary NO_2 from traffic sources in determining annual mean NO_2 concentrations at such locations. Higher primary NO_2 is associated with a greater proportion of the emissions being from diesel vehicles, particularly in slow moving congested traffic.
- Annual mean NO_2 concentrations monitored at urban background sites in the United Kingdom are broadly comparable with those monitored across Europe. Proximity to traffic appears to be the major determining influence on the annual mean NO_2 concentrations monitored at over 1600 sites across Europe. Annual mean exceedences of 40 µg m^{-3} NO_2 are widespread in urban centres across Europe.
- The use of models enables the extension of an analysis based on results of monitoring data to the whole country. The results of dispersion modelling studies for 2001 and 1999 are generally consistent with measurements in terms of exceedences of 40 µg m^{-3}. Exceedences are currently widespread throughout the London conurbation in the immediate vicinity of heavily-trafficked roads. These areas of exceedence spread further into urban background locations and fill much of the space between the major road links (A roads and motorways) in the centre of London.
- Detailed dispersion modelling studies indicate that in 1999 annual mean NO_2 concentrations exceeded 40 µg m^{-3} in London over 34-68% of the total area and alongside 95-98% of major roads (at about 5–10 m from the edge of the road) . The national models suggest that in 2001 concentrations were above this level alongside 90% of major roads in London, 33% in the rest of England, 17% in Scotland and 5% in Wales and Northern Ireland.

- Episodes when hourly mean NO_2 concentrations exceed 200 µg m^{-3} can be classified into two types. Winter episodes are associated with poor dispersion of primary NO_x emissions. Under these circumstances, elevated NO_2 concentrations are derived from a combination of NO_x emitted as primary NO_2 and emitted as NO followed by reaction with oxygen (O_2), superimposed on the regional background oxidant level which results from the reaction of emitted NO with O_3. Summer episodes are characterised by the elevated secondary NO_2 concentrations associated with regional scale photochemical oxidant episodes.
- An analysis of the occurrence of NO_2 episodes since 1988 shows that such episodes have become less common, with summer episodes becoming relatively less important than winter episodes in terms of their contribution to the total number of hours with concentrations in excess of 200 µg m^{-3}.
- Northern hemisphere mean O_3 baseline concentrations have shown an upward trend at the Mace Head site in Ireland of 1 µg m^{-3} (0.5 ppb) per year averaged over the period from 1987–2001. An increase in the oxidising capacity of this magnitude of rural air entering urban areas could lead to increased urban NO_2 concentrations.

Projected NO_2 concentrations in 2005 and 2010

- Empirical and dispersion model studies indicate that emissions reductions will lead to a significant reduction in exceedences of 40 µg m^{-3} at the roadside and in background locations, both nationally and in London.
- The national modelling projections, based on current national policies, suggest that in 2005 an annual mean concentration of 40 µg m^{-3} is likely to be exceeded alongside 65% of major roads in London, 18% in the rest of England, 8% in Scotland, 3% in Northern Ireland and 2% in Wales. By 2010 this is expected to reduce to 23% of major roads in London, 5% in the rest of England, 2% in Scotland and zero in Northern Ireland and Wales. These projections are broadly confirmed by detailed dispersion modelling studies for London. Projections of the extent of exceedence in background locations are less consistent between different models, which predict exceedence areas in Greater London of between 5-32% for 2005 and 3-13% for 2010.
- Traffic sources and the total of domestic and commercial emissions are predicted to each contribute roughly one third of the total annual mean NO_x concentration by 2010 in central London. The remaining third includes contributions from regional rural concentrations, industry, other area and point sources.
- NO_x emissions reductions in 2005 and 2010 to levels well below those expected to be delivered by current national policies will be required if an annual average concentration of 40 µg m^{-3} is to be met at *all* locations including the most highly polluted hot-spots.
- The current relationships between NO_x and NO_2 concentrations will not hold into the future if baseline O_3 concentrations increase and/or if the mass fraction of NO_x emitted directly as NO_2 also increases, leading in either case to increased difficulties with achieving an annual mean concentration of 40 µg m^{-3}. These issues highlight the complexities of predicting future NO_2 concentrations, involving the interactions of influences at global, regional and local scales.

Conclusions

- Widespread exceedences of 40 µg m^{-3} NO_2 as an annual mean remain, despite a decade of decreasing NO_x emissions. Annual mean NO_2 concentrations show significantly smaller downward trends than NO_x concentrations because of both limitations on chemical production and increased direct emissions of NO_2.
- With current national policies some exceedences of the annual mean objectives and limit values for NO_2 will remain in the years 2005 and 2010, respectively. These will be less widespread than at present, but nonetheless still appreciable. If future traffic flows exceed expectations, or emission control technologies fail to deliver anticipated reductions, continued exceedences will be more widespread.
- There is strong evidence that heavy duty diesel vehicles make a major contribution to NO_x emissions from UK road transport and to direct NO_2 emissions. In the context of meeting the National Emissions Ceiling Directive target for NO_x emissions in the UK, attention will also need to be given to forecasts of activity in the power generating sector, particularly in the fuel mix used for electricity generation.
- There are reasons to believe that the current projections for future urban NO_2 concentrations may be optimistic. If northern hemisphere baseline O_3 concentrations continue to rise and influence rural O_3 concentrations in the UK, then the relationships between urban NO_2 and NO_x concentrations will alter resulting in higher than expected future annual mean NO_2 concentrations. Furthermore, if catalytically-regenerative particulate traps that are being retrofitted to diesel powered vehicles dramatically increase direct emissions of NO_2, as indicated by studies carried out in the USA, there will be further breaches of the air quality objective and limit value.
- NO_2 should not be considered in isolation from other pollutants. In developing air pollution controls, there may therefore be trade-offs between different pollutants, and it is a matter of concern that much of local air quality management is currently driven by exceedences of one air quality objective: the annual mean of 40 µg m^{-3} for NO_2. The Expert Group feels that a more flexible and holistic approach to air quality management might deliver more effective control strategies.

Chapter 1

Introduction

1. The Air Quality Expert Group, AQEG, was established to help the Government and Devolved Administrations tackle air pollution by examining sources and concentrations of pollutants in the UK. It was set up following the publication of the *Air Quality Strategy for England, Scotland, Wales and Northern Ireland* with the following functions:

- To advise the Government on levels, sources, and characteristics of air pollutants in the UK;
- To assess the extent of exceedences of existing and proposed Air Quality Strategy objectives and EU limit values, where monitoring data are not available;
- To analyse trends in pollutant concentrations;
- To assess current and future ambient concentrations of air pollutants in the UK;
- To suggest potential priority areas for research aimed at providing a better understanding of the issues that need to be addressed in setting air quality objectives.

2. The aim of this report, the first by the Group, is to address these issues with respect to nitrogen dioxide (NO_2).

1.1 Effects of NO_2

3. The Air Quality Strategy objectives for NO_2 are primarily based on health effects. At relatively high concentrations, NO_2 causes inflammation of the airways. There is evidence to show that long-term exposure to NO_2 may affect lung function and that exposure to NO_2 enhances the response to allergens in sensitised individuals. This report will not address the health effects of NO_2 or indoor air pollution. In addition, NO_2 contributes to the formation of ozone (O_3) and of secondary particles and is implicated in acidification and eutrophication. Nitrogen oxides (NO_x) are associated with damage to vegetation and an EU limit value has been set to protect vegetation[1]. However, no further considerations given to this aspect of NO_x in this report. The subject was dealt with in the National Expert Group on Transboundary Air Pollution (NEGTAP) Report on Transboundary Air Pollution: Acidification, Eutrophication and Ground-Level Ozone in the UK, published in 2001.

1.2 Emissions

4. All combustion processes in air produce oxides of nitrogen. Nitrogen dioxide (NO_2) and nitric oxide (NO) are both oxides of nitrogen and together are referred to as NO_x. It is NO_2 which is associated with adverse effects upon human health. Road transport accounts for about half of total UK emissions of NO_x, with further major contributions from the electricity supply industry and the industrial and commercial sectors. In London, road transport accounts for over two thirds (68%) of emissions. UK NO_x emissions have declined substantially since a peak in 1989, with overall reductions of 38% to 2000. The decline is mainly due to reductions from road transport and electric power generation, through the use of catalysts and low NO_x burners, respectively. Emissions are likely to decline further over the coming years as new technology and emissions standards continue to be introduced. Estimates of current and future emissions

1 Applies to vegetation more than 20 km from an agglomeration; and more than 5 km away from industrial sources regulated under Part A of the 1990 Environment Act, motorways and built up areas of more than 5,000 people.

are provided via emissions inventories, which allocate emissions to categories, for example, road transport and power generation, and also provide spatial maps. The National Atmospheric Emissions Inventory (NAEI) covers the whole of the UK, mapping emissions on a 1 km x 1 km spatial grid. There are, in addition, several local inventories for example, the London Atmospheric Emissions Inventory (LAEI).

5. NO forms the principal component of emitted NO_x, although primary emissions of NO_2 are significant. NO is converted into NO_2 in the atmosphere, mainly by reaction with O_3. The conversion depends on the amount of O_3 available, so that the NO_2 concentration, and its dependence on NO_x, depends on both meteorology (transport of O_3-containing air to the point of emission and of NO_x-containing air into the surroundings) and chemistry. As a result, the estimation of future concentrations of NO_2 based on predictions of NO_x emissions is not easy and relies on models. These models are largely based on either previous measurements of NO and NO_2 and the development of relationships between NO_2 and NO_x, for a range of locations (roadside, urban background, etc) or on simple chemical relationships.

1.3 Measurements of NO_2 and NO_x

6. The UK has an extensive national network of 85 automatic monitoring sites measuring NO_x, comprising the Automatic Urban and Rural Network (AURN) and some affiliated sites from the London Air Quality Network (LAQN). The AURN sites include both those operated for Defra and the Devolved Administrations and some owned and operated by other organisations, mainly local authorities. These sites all use chemiluminescent analysers to measure both NO and NO_2. In addition, there are several regional networks operated, for example, by the Highways Agency and the power generators. Extensive measurements have also been made using diffusion tubes. The collective measurements, some extending over more than 10 years, provide an invaluable resource with which to assess the temporal and spatial variations in NO_2 and NO_x, including exceedences of the air quality objectives. These data have been used extensively in this report.

Box 1.1. Units of measurement

Regulations in the United Kingdom have, until recently, expressed concentrations of nitrogen oxides (NO_x) in units of parts per billion (1,000,000,000) – ppb. This is the ratio of the number of nitrogen dioxide (NO_2) molecules, for example, to the total number of molecules in the volume of air of interest. These units have the advantage that if the temperature or pressure of the air changes, the ratio remains the same.

European legislation sets limit value concentrations as micrograms of pollutant per cubic metre of air (μg m^{-3}). When these units are used without correcting to a standard temperature and pressure, the same 'packet' of air will have a different concentration as these properties of the air change. The legislation specifies that the air volume must be corrected to be at a standard temperature of 293 K (about 20°C), and a pressure of 101.3 kPa (about average atmospheric pressure at sea level).

For these conditions the conversion factors between the two sets of units are:

for nitrogen dioxide (NO_2) 1 ppb = 1.913 μg m^{-3}

for nitrogen oxide (NO) 1 ppb = 1.248 μg m^{-3}.

When considering the sum of NO and NO_2 (defined as NO_x), it is desirable to express the concentration in a way that remains constant if any of the NO becomes oxidised to NO_2. One way to achieve this is to use ppb units, where the NO_x concentration in ppb is the sum of the NO and NO_2 concentrations in ppb. However, this is not the case if NO_x is given in μg m^{-3} as the sum of the NO and NO_2 concentrations in μg m^{-3}.

When NO_x is given in units of μg m^{-3} in this report, it is calculated as if all the NO has been oxidised to NO_2. This is done by adding the concentrations of NO and NO_2 as ppb, and converting the sum to μg m^{-3} using the conversion factor for NO_2 given above. The unit is written *μg m^{-3}, as NO_2*. The same convention is required when reporting NO_x concentrations for the European legislation. Throughout this report NO_x in μg m^{-3} is expressed as NO_2.

1.4 Modelling

7. While the monitoring sites have a wide spatial coverage, they can clearly provide only a scattered representation of pollutant concentrations – they do not, in themselves, provide a complete UK map of NO_2 concentrations. In addition, they cannot be used in a simple way to project future concentrations and to assess future exceedences, because of the complex nature of both the likely future emissions and the relationship between NO_x and NO_2. As a result, modelling is essential to assess the linkage between estimates of emissions and of atmospheric concentrations, to interpolate between monitoring sites to provide national maps, and to estimate future concentrations and exceedences. A fundamental approach, in which the meteorology and chemistry are modelled on all distance scales, from metres to many kilometres, using mathematical formulations, is not yet used for assessment purposes. An empirical approach, utilising statistical analysis of the large amount of monitoring data, coupled in some circumstances with modelling of dispersion, has been widely used in the UK and forms a central component of the analysis and projections presented in this report. It is coupled with surface concentration modelling in the generation of maps of NO_2 concentrations across the UK. More fundamentally-based or deterministic models also have an important role to play and are used in this report, particularly to test the assumptions implicit in the empirical projections.

1.5 Policy background

8. NO_2 emissions and concentrations in the UK are subject to a number of national and international agreements and initiatives. These are outlined below and are described in more detail in individual chapters, where appropriate.

1.5.1 International legislation and agreements

9. There are three EU Directives that relate directly to concentrations of NO_x in the air:

a) The *First Air Quality Daughter Directive* (1999/30/EC) which sets limit values for hourly and annual average NO_2 to be achieved throughout the Community by 1 January 2010.

b) The *National Emission Ceilings Directive* (2001/81/EC) (NECD) which establishes a national limit for each Member State for emissions of certain atmospheric pollutants including NO_x. The NECD incorporates (and in some cases goes beyond) ceilings established earlier under the *UNECE Convention on Long-Range Transboundary Air Pollution Gothenberg Protocol.* Under the Directive the UK is committed to reducing its national annual emission of NO_x to below 1167 kt by 2010.

c) The *Third Air Quality Daughter Directive* (2002/3/EC) which primarily establishes a target (rather than limit) value for O_3 but also requires monitoring for NO_2 and for O_3 precursors.

Table 1.1 EU Limit values and air quality strategy objectives for NO_2.

Legislation	Hourly (µg m^{-3}) objective	Annual (µg m^{-3})	Achieve by
EU First Daughter Directive (99/30/EC)	200 µg m^{-3} with up to 18 exceedences per year	40	2010
Air Quality Strategy (2000)	200 µg m^{-3} with up to 18 exceedences per year	40	2005

10. The *Auto-Oil Programme* introduced tighter European vehicle emission and fuel quality standards. In 1998 three Auto-Oil proposals for further standards from 2000 were agreed. The key elements to this agreement – now consolidated into two directives – are:

- stringent series of emission standards for cars and light vans, (known as the Euro III standard) to apply to all new vehicles sold from January 2001, and for heavy-duty vehicles from October 2001;
- more stringent standards applying from 1 January 2006 (Euro IV standards) and for heavy-duty vehicles from October 2006;
- tighter fuel quality specifications which apply to all petrol and diesel sold from 1 January 2000 and 2005; and
- a ban on the general marketing of leaded petrol from 1 January 2000.

11. For industrial plants, two additional directives provide (either directly or indirectly) controls on emissions of NO_x: The *Large Combustion Plant Directive* (2001/80/EC) establishes controls on emissions from large combustion plants, which include power stations, oil refineries and large energy producers in industry, particularly the metals sector.

12. The *Integrated Pollution Prevention and Control (IPPC) Directive* (Directive 96/61/EC) requires site specific permits, that take account of the characteristics of each installation, its location and the state of the local environment. A wide range of installations and environmental impacts are taken into account by the regulator in considering a permit application. Conditions must be included to address any transboundary pollution from the installation. The Directive requires individual industrial plants to take any measures necessary to comply with relevant European Community legislation.

1.5.2 National framework

13. *Part IV of the Environment Act 1995* required the Government to produce a *National Air Quality Strategy* containing standards and objectives and measures to achieve the objectives. The first edition of the Strategy, published in 1997, fulfilled that requirement. This was reviewed in 1999 and the *Air Quality Strategy for England*, *Scotland*, *Wales and Northern Ireland* was published in January 2000. The Act also laid the foundations for the system of local air quality management.

14. *Local Air Quality Management* (LAQM) forms an important part of the Government's strategy to meet both the UK air quality objectives and EU limit values. The strategy recognises that national measures, for example, controls on emissions from new motor vehicles, will not always be the most appropriate way to deal with localised hot-spots. LAQM requires all local authorities to carry out regular reviews and assessments of air quality in their area, with a view to identifying all those locations where one or more of the objectives is unlikely to be met by the relevant date, taking account of relevant exposure (Defra, 2003). Such locations have to be formally designated as Air Quality Management Areas (AQMAs) and an Action Plan prepared to move towards meeting the objectives. The LAQM process, now in its fifth year, has identified the need for 132 local authorities, out of 407 in England, Scotland and Wales (Northern Ireland is working to a different timetable) to declare air quality management areas. Of these, 92% are for NO_2, 45% for PM_{10}, mostly in combination with NO_2, and 4% for sulphur dioxide. The NO_2 declarations are all for road traffic, although in some cases in combination with a contribution from industry. NO_2 is thus the principal pollutant driving the LAQM process. These local studies of NO_2 have generated information that supplements the findings of the national studies, and both are drawn upon in this report. For instance, while the national studies are inevitably focused on London and other major conurbations, as well as on the most heavily trafficked roads, the LAQM studies have shown that exceedences can also occur in smaller towns, where narrow streets coincide with congested traffic.

15. The Greater London Authority Act received Royal Assent in November 1999. It provides for the Mayor of London to prepare and publish a *Mayor's Air Quality Strategy* (MAQS) for Greater London. London local authorities must take the MAQS into account when exercising their functions under Part IV of the Environment Act 1995.

16. The MAQS, published in September 2002, sets out how the Mayor intends to implement the national Strategy in Greater London and achieve the objectives in the relevant regulations. It also contains:

- information about the current and likely future air quality in Greater London;
- the measures which are to be taken by the Greater London Authority, Transport for London and the London Development Agency;
- information about measures the Mayor will encourage other people and organisations to take; and
- any other proposals and policies the Mayor considers appropriate.

17. *Part I of the Environmental Protection Act 1990* has been the main mechanism for minimising air pollution from industrial sources for a number of years. This Act established two pollution control regimes: the *Local Air Pollution Control* (LAPC) regime and the *Integrated Pollution Control* (IPC) regime, which not only took account of releases to air, but also to land and water.

18. IPC and LAPC are being succeeded by the new pollution prevention and control (PPC) regimes implementing the Integrated Pollution Prevention and Control (IPPC) EC Directive 96/61. There are separate regulations in Scotland and it will be for the new Executive to determine the arrangements in Northern Ireland. Although the terminology used differs slightly, the principles underpinning both IPC and PPC are similar. Regulators are required to ensure that pollution from industry is minimised through the use of the best available techniques, which takes into account the balance between the costs and environmental benefits. Both systems also require regulators to take account of the characteristics of each installation, its geographical location and local environmental conditions. In England and Wales, PPC is regulated by the Environment Agency and local authorities, in Scotland, by Scottish Environment Protection Agency (SEPA). In Northern Ireland, PPC is the responsibility of the Industrial Pollution and Radiochemical Inspectorate of the Environment and Heritage Service and district councils.

Box 1.2. Exposure

The effects of an air pollutant are related to the total exposure to the pollutant over the relevant averaging period. In the case of NO_2 these are both 1-hour and annual periods. This exposure will take place in a whole range of micro-environments, each with its own concentration pattern. Epidemiological health effects studies inevitably simplify the measure of exposure, usually characterising the exposure of a large population group using a relatively small number of monitoring sites. These studies form the basis, in large part, of the air quality standards to protect human health. The standards, when translated into legislation, usually make clear where they are to be applied. Thus the air quality regulations that bring into force the air quality objectives in the UK state that they are to be applied at locations:

a) which are situated outside of buildings or other natural or man-made structures above or below ground; and

b) where members of the public are regularly present.

This text still leaves the relevant locations at which to apply the objectives open to interpretation. To help deal with this, further guidance has been provided on where the objectives should be applied (Defra, 2003). Thus for the annual mean NO_2 objective the relevant roadside location is the façade of a residential building, while for the 1-hour objective it would be the pavement of a street where people might regularly spend up to an hour, for instance a street with pavement cafes. The guidance in particular makes clear that the UK objectives only apply where there is exposure (or likely future exposure) that relates to the relevant averaging period.

The EU Directive setting limit values for NO_2 specifies that the siting of monitoring stations should be in areas where 'the highest concentrations occur to which the population is likely to be directly or indirectly exposed for a period which is significant in relation to the averaging period of the limit value(s)'. There is further detail in the Annexes as to where to monitor, for instance, traffic orientated samplers should be at least 25 m from the edge of major junctions, with the sampler no more than 5 m from the kerb and no closer than 4 m from the centre of the nearest traffic lane, i.e. ~2 m from the kerb. Also, the sampling points should represent air quality in a surrounding area of no less than 200 m^2. It should be noted though that draft Guidance from the Commission suggests that there may be some ambiguity between the Framework and Daughter Directives as to where limit values apply, although it is assumed in the document that a pragmatic approach will be applied to assessing compliance, taking exposure into account (Guidance on Assessment under the EU Air Quality Directive, available at: www.europa.eu.int/comm/environment/air/ambient.htm)

The issue of where objectives and limit values apply may ultimately be clarified by way of a legal ruling. In the absence of this, the Expert Group adopts the pragmatic view that exposure is a key factor when assessing the results of monitoring and modelling in relation to compliance with both objectives and limit values.

1.6 Structure of the report

19. This report aims, for the specific case of NO_2, to fulfil the tasks placed on AQEG and outlined in the Introduction to this chapter. Chapters 2–5 review the main issues relating to (i) the construction of emissions inventories, (ii) the measurement of NO and NO_2, (iii) the impact of meteorology and chemistry on NO_2 concentrations and (iv) modelling and mapping of NO_2 concentrations. Where possible and appropriate, we have included a discussion of fundamental as well as practical issues.

20. Chapter 6 provides a detailed analysis of data and an examination of historic trends. Data on annual mean NO_2 were assembled for 212 sites and are provided, with appropriate additional data, on the AQEG website (http://www.defra.gov.uk/environment/airquality/aqeg/index.htm). The data are used to examine exceedences and to construct both background and roadside national maps of NO_2 concentrations for 2001. In addition, 15 sites, covering all site-types, were selected for more detailed examination of hourly data. This analysis facilitates an optimisation of the empirical models and the development of a more detailed understanding of, for example, the linkage between NO_2 and traffic flow and the effects of meteorology. The chapter also includes an analysis of both wintertime and summertime episodes and an examination of European data to provide a European context.

21. In Chapter 7 projected concentrations for 2005 and 2010 are calculated and examined. Site specific projections are made for the 15 sites selected for detailed analysis, while simple projections of annual means are made for all of the sites and national maps constructed. Particular attention is focused on London, because of the wealth of data and the comparatively high incidence of exceedences of the annual mean limit value. This analysis also facilitates an understanding of the implications of national projections in other cities. Trajectory models are employed to examine the impact of policy measures and to test the effects of global issues, such as the increase observed in background tropospheric O_3 and the likely impact of climate change. Each chapter provides a list of key points and conclusions.