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1 EXECUTIVE SUMMARY

- Milton Keynes Council has completed a three-stage review and assessment of air quality in the Borough.

- Recent National and European air quality legislation, policy and guidance are reviewed.

- This report summarises the outcomes of the first stage review and assessment. Pollutant concentrations have been re-assessed in line with revised objectives and new government guidance published since the completion of the first stage report.

- The air quality objectives for benzene, 1,3-butadiene, lead and sulphur dioxide are currently being met and should still do so by the prescribed date. (2003-5)

- Milton Keynes Council has proceeded to a more detailed third stage review and assessment, for the pollutants nitrogen dioxide (NO$_2$), particulate matter (PM$_{10}$) and carbon monoxide (CO).

- CES environmental consultants were commissioned by Milton Keynes Council Environmental Health Division to undertake the third stage air quality dispersion modelling, to predict future pollutant concentrations.

- The air quality objectives for carbon monoxide and particulate matter are currently being met. Predicted concentrations are also expected to meet the objectives.

- The annual objective for nitrogen dioxide is currently being exceeded at some locations adjacent to the M1 motorway.

- An exceedance of the annual objective for nitrogen dioxide in 2005 is predicted within 20-30 metres either side of the edge of the M1 motorway at busy sections.

- As there are no residential properties within this area, members of the public are not exposed to levels of nitrogen dioxide above the annual objective concentration. Local action to control air quality as a result of the exceedance, will not be necessary.

- An Air Quality Management Area (AQMA) is not required in the Borough of Milton Keynes.

- An enhanced monitoring program will collect data to be used for the second Review and Assessment of air quality, to be completed by the end of 2003.
2 INTRODUCTION

This is a consultation report on the existing and predicted air quality in the Borough of Milton Keynes. The report summarises the findings of the earlier First Stage review and assessment report published March 1999, and describes the additional monitoring and modelling work that has been undertaken to complete the review and assessment procedure. It was decided to proceed directly to a more detailed Third Stage review and assessment, without undertaking the Second Stage additional screening methods.

The 1st stage report identified the possible exceedance of an objective for the pollutants nitrogen dioxide (NO₂) and particles (PM₁₀). As the Third Stage requires the use of sophisticated modelling techniques, CES (Consultants in Environmental Science) were commissioned to undertake this work.

CES have used a dispersion model known as AAQuIRE, to investigate current air quality and to predict future air quality. CES have assessed whether the air quality objectives for NO₂, and PM₁₀ are likely to be achieved within the relevant time period. When all the necessary input data for AAQuIRE had been collated and used for modelling NO₂ and PM₁₀ levels, CES were asked to run the dispersion model for the pollutant carbon monoxide (CO), primarily to predict CO concentrations close to the M1 motorway.

The focus of the review and assessment is on outdoor locations where members of the public are regularly present and are likely to be exposed over the averaging period of the pollutant objective e.g. this may be an annual mean or an hourly mean.

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2.1 An Overview of the Borough of Milton Keynes

The Borough covers an area of 30,869 hectares in North Buckinghamshire. Its boundary forms the county boundary with Northamptonshire to the north and west, and with Bedfordshire to the east. To the south of the Borough is the Aylesbury Vale District of Buckinghamshire. The “new city”, or Designated Area of Milton Keynes, accounts for about one third of the Borough, and contains approximately 80% of the total population of approximately 209,000.
The rivers Great Ouse, Ouzel and Tove, along with the Grand Union Canal pass through the Borough. The M1 motorway and the electrified mainline railway from London Euston to Scotland run south-east/north-west through the Borough. The non-electrified single-track railway from the south-west to Bedford via Bletchley passes through the Borough and is used by diesel locomotives to carry passengers and freight. The line is currently being upgraded and is likely to connect to the east coast port of Harwich. The city has a grid road system with roundabout junctions, to facilitate free flowing traffic, and has an integral “redway” system for pedestrians and cyclists. A network of equestrian routes is also available.

Since being designated as a “new city” in 1967, Milton Keynes has experienced one of the fastest rates of growth in the country, attracting major new employers and facilities. This growth is likely to continue as the Government has recently proposed Milton Keynes as an area for further major expansion. There are two main expansion areas on the eastern and on the western sides of the new city, and a smaller area to the north. Sites for approximately 9250 new houses have been identified up to 2011 in the Local Plan (2000). Part of the eastern expansion area north of the A421 is planned for large footprint warehousing and distribution.

Major business, shopping and leisure activities are concentrated in the Central Milton Keynes grid square. A new theatre and gallery complex opened in autumn 1999. “Xscape”, an integrated leisure and retail complex, incorporating an indoor ski slope, multiplex cinema, fitness centres and retail outlets opened in spring 2000. The regional shopping centre has been extended by 33% to provide a new department store and over 70 retail units.

The remaining parts of the Borough are essentially rural in character, containing two Areas of Attractive Landscape; along the Great Ouse Valley and in the wooded area of The Brickhills. There are a number of attractive small towns and villages throughout the Borough and numerous parks and lakes, particularly within the designated area of the “new town”.


3 OUTCOMES OF THE FIRST STAGE REVIEW AND ASSESSMENT

In the First Stage review, seven pollutants listed in the Air Quality Regulations 1997 were assessed to determine the likelihood of the future year target objectives being exceeded in the Borough of Milton Keynes. The First Stage identified the need to proceed to a more detailed Second or Third Stage review and assessment for the pollutants nitrogen dioxide and particulate matter (PM$_{10}$).

Since the completion of the First Stage review and assessment the National Air Quality Strategy (NAQS) has been revised, and the Air Quality Regulations 1997 have been replaced with new Regulations. The changes are described in more detail in this report. Government guidance on the review and assessment procedure has also been updated, and the summary below of the First Stage findings takes these changes into account.

Benzene

The air quality objective for benzene is a running annual mean of 16.25 µg/m$^3$ (5 ppb), to be achieved by the end of 2003. The First Stage review and assessment collated details of industrial processes regulated under Part 1 of the Environmental Protection Act 1990, and it was determined that there are no significant sources of benzene within the Borough or in neighbouring areas. It is assumed that petrol stations do not give rise to significant emissions of benzene. Petrol vapour displaced from storage tanks during tanker deliveries is no longer vented to atmosphere, and has to be recovered by backventing into the tanker. This process is known as vapour recovery.

Data from national network monitoring sites (Birmingham East and London Eltham), show the 1998 annual running mean to be 3.25 µg/m$^3$ (1 ppb). The amount of benzene in petrol has been reduced progressively to a maximum of 1% by volume as from January 2000. An exceedance of the air quality objective is therefore unlikely, and a second stage review and assessment has not been undertaken for this pollutant.

1,3-Butadiene

The adopted air quality objective for 1,3-butadiene is a running annual mean of 2.25 µg/m$^3$ (1 ppb) to be achieved by the end of 2003. Exhaust emissions from motor vehicles is the main source of 1,3-butadiene in the United Kingdom, but it is an important industrial chemical handled in bulk at some industrial premises. There are no existing or proposed significant industrial sources within the Borough or in neighbouring areas. Emissions from road traffic are not considered to be significant. National network monitoring site data
(1998) showed the objective is being met at London UCL roadside location (0.91 µg/m³), and at urban background sites e.g. Birmingham East (0.45 µg/m³).

The increasing use of three-way catalysts in vehicle exhaust systems has brought about further reductions in vehicle emissions. Improvements to fuel quality (Auto-Oil programme) are expected to reduce emissions of 1,3-butadiene in future years. It is therefore unnecessary to proceed beyond a First Stage review and assessment for 1,3 butadiene.

**Lead**

There are two air quality objectives for lead. The first is 0.5 µg/m³ as an annual mean to be achieved by the end of 2004, equivalent to the limit value set in the European Union (EU) Air Quality Daughter Directive. However, Government policy is to reduce the concentration of lead in air to a level as low as reasonably practicable. A second objective of 0.25 µg/m³ to be achieved by the end of 2008 has therefore been set.

The sale of leaded petrol in the United Kingdom has been banned since January 2000, consequently road traffic emissions do not need to be considered as a significant source of lead. There are no existing or proposed significant industrial sources within the Borough or in neighbouring areas. It is therefore unnecessary to proceed beyond a First Stage review and assessment for lead.

**Sulphur dioxide**

There are three air quality objectives set for sulphur dioxide. The first is a 1-hour mean of 350 µg/m³ (132 ppb) not to be exceeded more than 24 times per year, to be achieved by the end of 2004. The second is a 24-hour mean of 125 µg/m³ (47 ppb) not to be exceeded more than 3 times a year by the end of 2004. The third and most stringent standard is a 15-minute mean of 266 µg/m³ (100 ppb) not to be exceeded more than 35 times a year, to be achieved by the end of 2005.

Analysis of data from automatic UV-fluorescence sulphur dioxide monitors, installed in February 1999 at the Civic Offices, and in November 1998 at the mobile air quality station, has shown no exceedances of the above air quality objectives. The daily average sulphur dioxide concentration is also measured at Rickley Park, Bletchley using a chemical method (8-port gas bubbler). This apparatus was installed in 1969 and results have shown that the concentration of SO₂ has fallen dramatically over the years. The reduction was brought about locally by the closure of the brickworks in Newton Longville and Bletchley, and by the implementation of a Smoke Control Area program in Bletchley and Milton Keynes in the 1970’s. As national emissions of SO₂ are expected to fall even further in future years, e.g. with the introduction of regulations limiting the sulphur content of liquid fuels, further assessment was unnecessary.
Carbon monoxide

The air quality objective for carbon monoxide is an 8-hour running mean of 11.6 mg/m$^3$ (10 ppb) to be achieved by the end of 2003. The First Stage report used data from nearby Department of the Environment, Transport and the Regions (DETR) sites, (Oxford City, Birmingham East and Leicester Centre) to determine the likelihood of exceedance of the statutory target. Although it was concluded that the 2003 objective was unlikely to be exceeded, further investigation using dispersion modelling has been undertaken. Road traffic accounts for about 75% of emissions of carbon monoxide and it was therefore considered important to assess levels close to the M1. This did not involve a great deal of extra work as all the necessary input data files were already programmed into the AAQuiRE model. Real-time automatic CO analysers have been added to the static and mobile air quality stations in July 2000, which will enable the modelled data to be more accurately validated.

Nitrogen dioxide

The Government has adopted the EU Daughter Directive objectives of an annual mean of 40 µg/m$^3$ (21 ppb), and a 1-hour mean objective of 200 µg/m$^3$ (105 ppb) not to be exceeded more than 18 times a year. Both nitrogen dioxide objectives are to be achieved by the end of 2005. The Expert Panel on Air Quality Standards (EPAQS), who advise the Government on the health effects of air pollutants, recommended a short-term health-based standard of 297 µg/m$^3$ (150 ppb) as an hourly mean, with no allowed exceedances. This standard will be achieved in meeting the more stringent EU objective. The First Stage report used data from the automatic nitrogen dioxide analysers contained within the two air quality stations, and from the Council’s extensive passive diffusion tube monitoring network which has been in existence since 1992.

Real-time automatic data indicated that there was a significant risk of the air quality objectives not being met by the end of 2005, in certain areas. Diffusion tube data also indicated possible exceedances of the annual mean standard, but there was a general trend of declining NO$_2$ levels since commencement of the network in 1992.

A more detailed Third Stage review and assessment has therefore been undertaken for nitrogen dioxide.

PM$_{10}$ (Fine Particles)

There are two air quality standards for fine particles PM$_{10}$, which are equivalent to the EU Stage 1 Limit Values. The standards are 40 µg/m$^3$ as the annual mean and 50 µg/m$^3$ as a fixed 24-hour mean not to be exceeded on more than 35 days per year. Both standards are to be achieved by the end of 2004.
The First Stage report used data from the "TEOM" automatic PM$_{10}$ analysers contained within the two air quality stations and other data gathered from Automatic Urban and Rural Network (AURN) sites throughout the country, for comparison with Milton Keynes. The data did not show any current exceedances of the standards during the monitoring period. However, it was decided to proceed to a Third Stage review and assessment to model predicted levels near busy roads where there is a risk of objectives being exceeded.
4 AIR QUALITY LEGISLATION, POLICY AND GUIDANCE

4.1 Overview of Recent Air Quality Legislation and Policy

Part IV of the Environment Act 1995 introduced the system of Local Air Quality Management (LAQM). Under the Act, the Government was required to develop a National Air Quality Strategy for the UK (the Strategy). This Strategy was published in March 1997 and was endorsed by the present Government in July 1997, as an essential part of the Government's strategy for sustainable development.

The Strategy contains 8 health-based standards and objectives to be achieved in outdoor, ambient air. Occupational exposure, indoor air quality and in-vehicle exposure is not included in its scope. The Strategy also identifies action to be taken at international, national, and local levels to achieve these objectives.

The Air Quality Regulations 1997 brought into legal effect seven of the standards and objectives in the Strategy for the purposes of LAQM. Ozone was not prescribed in the Regulations because of its transboundary nature, and the difficulty of controlling it at a local level. It is therefore outside the scope of LAQM.

The Strategy has recently been reviewed and the second edition was published in January 2000. It is entitled "The Air Quality Strategy for England, Scotland, Wales, and Northern Ireland" and as the title suggests the devolved administrations in Scotland and Wales have continued with the joint UK approach. The new Strategy reviews the same eight pollutants first identified in the 1997 Strategy. The 1997 Air Quality Regulations have now been replaced by the Air Quality (England) Regulations 2000 to reflect the changes made to the standards and objectives.

The statutory responsibility for the review and assessment of air quality and certain other requirements of LAQM, falls to the local authority, with the aim of improving air quality at a local level. However, as with the first edition, the Strategy is intended not just for environmental regulators, but also for business, industry and individuals who all have a role to play in reducing atmospheric emissions.

Section 82 of the Environment Act 1995 (the Act) requires local authorities to review and assess air quality within the authority’s area, periodically. Where an air quality standard or objective is not likely to be achieved within the relevant time period, in a relevant location, the local authority must, by order under Section 83 of the Act, designate the affected area as an Air Quality Management Area (AQMA). The order designating an AQMA can be varied by a subsequent order, or revoked if future air quality assessments indicate that objectives are likely to be achieved.

Action at a local level must then be taken to bring about improvements in air quality within the AQMA, in order to achieve the relevant standards and objectives. The local authority
must prepare and publish for consultation, a written Action Plan setting out proposals for air quality improvements within the designated area. At the same time, local authorities are required to carry out a further review and assessment (“Stage 4”) of existing and likely future air quality in an AQMA, and produce a report for consultation within 12 months of AQMA designation. This will be an opportunity to consolidate earlier findings, determine how great an improvement is needed to meet the objectives, and calculate which different sources contribute to the problem. The action plan is produced with input from other agencies, business, industry, community groups, individuals, adjoining councils, to provide a balanced and integrated approach. Actions to be taken need to be cost-effective and proportionate to the contribution of the different pollution source to the exceedance. The environmental, economic and social consequences of proposed actions have to be carefully considered.

The action plan should include a timetable for implementing the plan. Councils are required to consult on their draft action plans within 9-12 months of AQMA designation, and aim to have the action plan in place within 12-18 months of designation. The action plan can be revised by the Council as necessary.

A second review and assessment of air quality throughout the Borough of Milton Keynes, must be completed by the end of 2003.

The local authority is able to bring about improvements in air quality by the enforcement of other legislation including the Clean Air Act 1993, and the Local Air Pollution Control (LAPC) system under Part 1 of the Environmental Protection Act (EPA) 1990. The LAPC system regulates atmospheric emissions from certain industrial processes. The Pollution Prevention and Control Act 1999 (PPC Act), and The Pollution Prevention and Control (England and Wales) Regulations 2000, will replace and enhance the provisions in Part 1 of the EPA. Industrial installations will be phased into the new system in sectors over the next few years. The land-use planning system also has an integral role to play in improving air quality and achieving air quality objectives.

4.2 Revised National Air Quality Strategy 2000 / European Directives

The standards adopted in the Strategy are based mainly on the recommendations of the Expert Panel on Air Quality Standards (EPAQS). EPAQS was set up in 1991 to provide independent advice on air quality issues, in particular the levels of pollution at which no or minimal health effects are likely to occur. Members of the Panel are primarily drawn from those eminent in the fields of health research, practice and teaching.

European legislation and agreements also have to be considered in forming the framework for the Strategy. In particular the Air Quality Framework Directive (Directive 96/62/EC) and associated Air Quality Daughter Directives place legal obligations on Member States to achieve the limit values for individual pollutants by specified dates. The EU limit values are
incorporated into the Strategy, and are subsequently prescribed as objectives for the purposes of LAQM.

The Framework Directive identifies twelve pollutants for which limit or target values will be set in subsequent Daughter Directives, superseding existing air quality legislation. The first Air Quality Daughter Directive, which was adopted in April 1999, established limit values for sulphur dioxide, nitrogen dioxide, particles and lead to be achieved by 1 January 2005 and 2010. The second Daughter Directive was adopted in September 2000 and sets limit values for carbon monoxide and benzene to be achieved by 2005 and 2010 respectively. Member States are required to implement the Directives within 2 years of them coming into force, and this is usually achieved by new Regulations. Local authorities are consulted on the draft versions of the Regulations.


The second edition of the Strategy includes revised health-based standards and objectives for the 8 pollutants identified in the first edition. There is a new standard and objective (not prescribed by regulation) for the protection of vegetation and ecosystems set for the pollutants nitrogen dioxide and sulphur dioxide.

The date for achieving some of the objectives has been brought forward from the December 31st 2005 timescale set out in the 1997 Strategy. The target date for benzene, 1,3-butadiene and carbon monoxide is now December 31st 2003, and for lead the target date is December 31st 2004, and December 31st 2008 (for a stricter standard). There is no change to the ozone objective.

Nitrogen dioxide may have both a short-term (acute), and long-term (chronic), effect on health, therefore two objectives have been set to be achieved by the end of 2005. In the revised Strategy the short-term objective has been reduced from 286 µg/m³ (150 ppb) to 200 µg/m³ (105 ppb) as a 1-hour mean not to be exceeded more than 18 times a year, and the long-term objective remains unchanged.

The original target for particles (50 µg/m³ as a running 24-hour mean 99th percentile) has been replaced by the European Directive Stage 1 limit values. This is a relaxation of the 1997 Strategy objective, which has been shown to be unachievable and was exceeded at most locations. There are now two objectives for PM₁₀, a 24-hour mean and an annual mean, both to be achieved by December 31st 2004. The 24-hour mean is 50 µg/m³ not to be exceeded more than 35 times per year, and the annual mean is 40 µg/m³. The 24-hour mean may be strengthened in advance of the next Strategy review depending on the outcome of current research into the sources and types of particles, and their effects on health.
For sulphur dioxide the national objective has been retained, and supplemented with European limit values based on the Air Quality Daughter Directive.

In the 1997 Strategy, the objective for standards with a short averaging time, was expressed in terms of percentile compliance, as it was recognised that 100% compliance was not always practicable. The EU Directive specifies an allowed number of exceedances. To avoid confusion and allow direct comparison between national objectives and EU limit values, the revised Strategy and Air Quality (England) Regulations 2000 now use this method. There is however, an approximate relationship between equivalent percentiles and permitted exceedances per year as given in table 4.1 below.

**Table 4.1 Approximate equivalent percentiles to the air quality objectives:**

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Time Period</th>
<th>Permitted Exceedances/year</th>
<th>Equivalent Percentile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen dioxide</td>
<td>1-hour</td>
<td>18</td>
<td>99.8&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>PM&lt;sub&gt;10&lt;/sub&gt;</td>
<td>24-hour</td>
<td>35</td>
<td>90&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>15-minute</td>
<td>35</td>
<td>99.9&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>1-hour</td>
<td>24</td>
<td>99.7&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
<tr>
<td></td>
<td>24-hour</td>
<td>3</td>
<td>99&lt;sup&gt;th&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

If the objective is to be complied with at the 99.9<sup>th</sup> percentile, then 99.9% of measurements at each measuring point in the relevant period (usually one year) must be at or below the level specified. Taking the example of 15-minute values, there should be 365 X 24 X 4 = 35040 measurements. All but the highest 0.1% of measurements must be at or below the value specified. In this case the highest 35 15-minute values.

The equivalent percentile is used in dispersion models to determine the likelihood of an objective being exceeded.
5 THIRD STAGE REVIEW AND ASSESSMENT - POLLUTANTS STUDIED

5.1 Nitrogen Dioxide (NO₂)

The current air quality objectives for nitrogen dioxide are given in Table 5.1.

The EPAQS recommended short-term health-based standard is unchanged at 286 µg/m³ (150 ppb), as an hourly mean with no permitted exceedances. This was the standard in the 1997 Strategy and Air Quality Regulations 1997, but it has been replaced in the 2000 revisions with the EU Daughter Directive standard of 200 µg/m³ (105 ppb) hourly mean, not to be exceeded more than 18 times per year. This approximates to a 99.8th percentile value.

Table 5.1 NO₂ Air Quality Objectives

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Measured as</th>
<th>Date to be achieved by</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 µg/m³ (105 ppb)</td>
<td>1-hour mean not to be exceeded more than 18 times a year</td>
<td>December 31st 2005</td>
</tr>
<tr>
<td>40 µg/m³ (21 ppb)</td>
<td>Annual mean</td>
<td>December 31st 2005</td>
</tr>
</tbody>
</table>

To convert concentrations of NO₂ between ppb and µg/m³, use the following factor:

\[ 1.91 \times \text{ppb} = \mu g/m³ \]
\[ 0.524 \times \mu g/m³ = \text{ppb} \]

Table 5.2 shows how different pollutant levels translate into the DETR's Air Pollution Information Service banding system. The low band indicates that pollution levels are less than the EPAQS hourly mean objective.

Table 5.2 NO₂ Air Pollution Information Service Bands

<table>
<thead>
<tr>
<th>Pollution Band</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than</td>
<td>286 µg/m³</td>
<td>286 µg/m³ (150 ppb) - 571 µg/m³ (299 ppb)</td>
<td>573 µg/m³ (300 ppb) to 762 µg/m³ (399) ppb</td>
<td>764 µg/m³ (400 ppb) or more</td>
</tr>
<tr>
<td>286 µg/m³ (150 ppb)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

To convert concentrations of NO₂ between ppb and µg/m³, use the following factor:

\[ 1.91 \times \text{ppb} = \mu g/m³ \]
\[ 0.524 \times \mu g/m³ = \text{ppb} \]
Introduction

Nitrogen dioxide (NO₂) and nitric oxide (NO) are both oxides of nitrogen and together are referred to as NOₓ. It is nitrogen dioxide that is associated with adverse effects upon human health. The majority of NOₓ emitted from vehicles is in the form of nitric oxide, which is then oxidised in the atmosphere to produce nitrogen dioxide, a secondary pollutant. NO₂ also contributes to secondary particle and ozone formation, and to the formation of acid rain. Appendix D gives further information on the atmospheric chemistry of NOₓ.

All combustion processes in air produce NOₓ with NO being the predominant oxide. The conversion of NO to NO₂ takes place in the atmosphere via a reaction with chemically active species such as ozone. The ratio of NO₂ to NO varies depending on the oxidising capacity of the atmosphere. In heavily polluted areas nitric oxide concentrations may exceed those of nitrogen dioxide. For example, at roadside locations nitric oxide concentrations normally exceed nitrogen dioxide concentrations. In background unpolluted areas nitric oxide levels are low due to oxidation of NO to NO₂ normally by reaction with ozone. However, the relative concentration of NO₂ is still greatest near to busy roads. The relationship between NOₓ:NO₂ has to be taken into account when undertaking dispersion modelling to predict future NO₂ concentrations.

NOₓ is one of the main contributors to acid deposition. Direct exposure of vegetation to NOₓ at high concentration may result in leaf damage or make plants more susceptible to attack by pests and diseases. The effects of NOₓ can be greatly influenced by the presence of other pollutants. In particular, NOₓ and sulphur dioxide can significantly reduce growth rates at higher concentrations.

The Effects of nitrogen dioxide on Health

EPAQS concluded that there is a threshold concentration of 3820 µg/m³ (2000 ppb), in healthy people, at which adverse health effects of short-term exposure cannot be detected. People with asthma are more sensitive to nitrogen dioxide and experimental inhalation studies have shown that adverse health effects are unlikely in asthmatics below 382 µg/m³ (200 ppb). A standard of 286 µg/m³ (150 ppb) measured over 1 hour was recommended which included a margin of safety to protect susceptible people.

The mechanism by which nitrogen dioxide acts is most probably related to its properties as an oxidising agent, which can damage cell membranes and proteins. At relatively high concentrations nitrogen dioxide causes acute inflammation of the airways. In addition, short-term exposure can affect the immune cells of the airways in a manner that might predispose people to an increased risk of respiratory infections.

People with healthy lungs, whether at rest or exercising, show little response to experimental inhalation of nitrogen dioxide at concentrations well above those occurring in the ambient air, even during extreme pollution episodes. Very small changes in sensitive
tests of lung function have been recorded at exposures between 2500 and 7500 ppb. However, in people with asthma, some studies have shown changes in these tests of lung function to have occurred at exposures of around 300 ppb when the subjects have been exercising, though other studies have shown no changes at higher concentrations. Measurements of the responsiveness of the lung to inhalation of irritant chemicals have shown that the airways of some people with asthma may become more sensitive to such stimuli after exposure to nitrogen dioxide at concentrations down to about 200 ppb.

Other studies have investigated the possibility that inhalation of nitrogen dioxide at moderate concentrations may cause an inflammatory reaction in the lungs or may increase the susceptibility of individuals to subsequent inhalation of allergens, such as those from house dust mite or grass pollen. The inflammatory reaction, if repeated frequently, might act to decrease the resistance of individuals to infection, and is more relevant to repeated exposures to elevated indoor levels than to exposure to the outdoor concentrations typically occurring in the United Kingdom.

At present, the evidence from both human and animal studies is open to different interpretations. However, there is some evidence that exposure to nitrogen dioxide can enhance the response of someone with asthma to inhalation of allergen. To date all these effects have only been demonstrated at concentrations of nitrogen dioxide that occur in the ambient air of the United Kingdom only in the most exceptional circumstances. During pollution episodes people appear to be affected by levels of nitrogen dioxide lower than levels producing effects in exposure chamber studies. It is likely that it is the mixture of pollutants, and adverse meteorological conditions that is the cause, rather than nitrogen dioxide alone.

It is more difficult to study long-term effects of nitrogen dioxide, and also concurrent exposure to other pollutants including indoor sources. There is less available information and evidence is contradictory, and relies on indirect measures of exposure.

Since exposure to nitrogen dioxide indoors is often an important contributor to the overall exposure of individuals, some studies have specifically investigated relationships between indoor exposure and health. Indoor concentrations of nitrogen dioxide in the kitchens of homes with gas cookers average, over a year, around 29 µg/m³ (15 ppb) and peak concentrations may be as high as 1146 µg/m³ (600 ppb) over an hour.

The outdoor concentration of nitrogen dioxide is the main determinant of indoor concentrations in homes without gas cookers, the concentrations generally being lower indoors. In homes with gas cookers, indoor levels are usually at or above outdoor levels, being higher in the winter months when homes are less well ventilated and more use is made of gas appliances. It should be borne in mind that gas cooking has much wider effects on the indoor environment and that these may also affect respiratory health, e.g. carbon dioxide, carbon monoxide, particles. The Panel have taken the view that a long-term effect of chronic exposure to nitrogen dioxide, whilst not yet demonstrated, cannot be ruled
out. Taking all the evidence into account the Panel did not set a standard for long-term exposure, but recommended a strategy to reduce annual average concentrations. The adopted long-term standard is derived from the WHO annual average guideline value of 40 µg/m³ (21 ppb).

**UK NO\textsubscript{x} Emission Estimates**

Since 1970 there has been a reduction in emissions of 24%. Up to 1984 the NO\textsubscript{x} emission profile was relatively flat with small peaks in 1973 and 1979, which were due largely to the cold winters in those years. However, from 1984, emissions rose markedly as a result of the growth in road traffic reaching a peak in 1989 (Table 5.3 and Figure 5.1). Since 1989, total emissions have declined by 32% as a result of a 52% reduction from power stations and 30% decrease from road transport.
Table 5.3 UK Annual Emissions of Nitrogen Oxides (ktonnes), 1970-1997

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<td>66</td>
<td>75</td>
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<td>38</td>
<td>38</td>
<td>37</td>
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Combustion in Industry

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<td>1233</td>
<td>1227</td>
<td>1176</td>
<td>1124</td>
<td>1076</td>
<td>1005</td>
<td>958</td>
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Other Transport/Machinery

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<td>79</td>
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<td>77</td>
<td>74</td>
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<td>4</td>
</tr>
<tr>
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Emissions by FUEL TYPE used in the above categories:

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<td>Solid</td>
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<td>858</td>
<td>764</td>
<td>681</td>
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<td>540</td>
<td>540</td>
<td>493</td>
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<td>408</td>
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<td>206</td>
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<td>233</td>
<td>233</td>
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<td>82</td>
<td>77</td>
<td>83</td>
<td>84</td>
<td>84</td>
<td>84</td>
</tr>
</tbody>
</table>

TOTAL 2427 2502 2673 2571 2497 2333 2242 2093 2018 1835 100%

Figure 5.1: Variation in Emissions of Total Oxides of Nitrogen (NOx)
**Transport**

The major source of NO\(_x\) emissions in the UK is the transport sector with road vehicles and off-road vehicles contributing 48% and 4%, respectively, to the total emission in 1997. Road traffic emissions rose steadily between 1970 and 1989 reflecting the overall growth in road traffic in the UK. During this period emissions from petrol vehicles, predominantly cars, rose by 87% compared to the 1970 level and emissions from diesel vehicles rose by 56%. Figure 5.2 clearly shows the growth in the vehicle fleet and vehicle mileage during this period. Since 1989 there has been a steady decline in emissions due to the introduction of catalytic converters on cars and stricter regulations on truck emissions.

Various emission regulations on new petrol cars which have come into effect in stages since 1976 have led to the gradual reduction in emission rates from petrol cars; the more rapid decline in emissions from 1992 is due to the penetration of cars fitted with three-way catalysts. Limits on emissions from diesel cars and light goods vehicles (LGV’s) did not come into effect until 1993/94. Overall emissions per kilometre from heavy goods vehicles (HGV’s) showed a small rise from 1970-1987 due to the increasing usage of larger HGVs for freight movement. Limits on emissions from HGVs first came into effect in 1988 leading to a gradual reduction in emission rates as new HGVs penetrated the fleet, accelerated by tighter limits on emissions from new HGVs in 1993/94.

**Figure 5.2 Emissions of NO\(_x\) from Road Transport by Vehicle Type**

![Chart showing emissions of NO\(_x\) from road transport by vehicle type.](chart.png)
Other transport and machinery contribute a further 11% to total UK NO\textsubscript{x} emissions. Of these only those from civil aircraft have grown steadily over the period from 1970 to 1997.

Forecasts of emissions of NO\textsubscript{x} from road transport in urban areas suggest decreases in emissions of 59% between 1995 and 2005. Emissions are projected to continue to decrease until 2020 before increasing again.

**Power Generation**

Emissions from power stations have declined over the period 1970-1997 by around 54%. Emissions in the seventies were fairly flat with peaks in severe winters. Since 1979 emissions have declined with a dip at the time of the miners strike in 1984. Prior to 1989 this decline was due to the increased use of nuclear power and an increase in the average efficiency of the thermal power stations. Since 1988 the electricity generators have adopted a programme of progressively fitting low NO\textsubscript{x} burners to their coal fired units. More recently the increased use of nuclear generation and the introduction of combined cycle gas turbine (CCGT) plant burning natural gas have further reduced NO\textsubscript{x} emissions. The emissions from the low NO\textsubscript{x} turbines used are much lower than those of pulverised coal fired plant even when low NO\textsubscript{x} burners are fitted. Given that these trends continue, power station emissions are expected to fall further.

**Industry**

The emissions from industrial combustion have declined by 54% since 1970 and they currently contribute 9% to total UK emissions. This is due to the decline in coal use in favour of gas and electricity.
5.2 Particulate Matter

The current air quality objectives for particulate matter are given in Table 5.4.

Table 5.4 PM$_{10}$ Air Quality Objectives

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Measured as</th>
<th>Date to be achieved by</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 µg/m$^3$</td>
<td>Fixed 24-hour mean not to be exceeded more than 35 times a year</td>
<td>December 31$^{st}$ 2004</td>
</tr>
<tr>
<td>40 µg/m$^3$</td>
<td>Annual mean</td>
<td>December 31$^{st}$ 2004</td>
</tr>
</tbody>
</table>

Table 5.5 below shows how different pollutant levels translate into the DETR's Air Pollution Information Service banding system. The low band indicates that pollution levels are less than the EPAQS hourly mean objective measured as a running 24-hour mean.

Table 5.5 PM$_{10}$ Air Pollution Information Service Bands

<table>
<thead>
<tr>
<th>Pollution band</th>
<th>Low</th>
<th>Moderate</th>
<th>High</th>
<th>Very high</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 50 µg/m$^3$</td>
<td></td>
<td>50 µg/m$^3$ - 74 µg/m$^3$</td>
<td>75 µg/m$^3$ to 99 µg/m$^3$</td>
<td>100 µg/m$^3$ or more</td>
</tr>
</tbody>
</table>

Introduction

Particulate matter is monitored in the UK as PM$_{10}$ i.e. particles generally less than 10 µm (10 millionths of a metre) in diameter. Particles occur in the air over a size range of 0.01 to 100 µm. Airborne particulate matter has both a primary and a secondary component.

Primary particulate matter is emitted directly into the atmosphere from a wide range of sources such as fuel combustion, surface erosion and wind blown dusts. Secondary particulate matter is formed in the atmosphere by the chemical reactions of gases such as sulphur dioxide, oxides of nitrogen and ammonia. Sulphate and nitrate particles are produced by these reactions, as well as organic aerosols formed from the oxidation of volatile organic compounds (VOC’s). Both primary combustion particles and secondary particles are fine particles generally less than 2.5 µm in diameter, long-lived in the atmosphere and can travel large distances. Non-combustion, resuspended and wind blown dusts are known as coarse particles and are generally greater than 2.5 µm in diameter.

Knowledge of emissions alone provides valuable insights into the sources of primary particles, but gives little insight into the contribution made by secondary particles to airborne
concentrations of PM$_{10}$. Receptor modelling uses measurements of the chemical and physical properties of airborne particles to assign them to different source categories as described in the report from the Airborne Particles Expert Group (APEG, 1999). This method shows there are three predominant contributors to PM$_{10}$ mass in the UK atmosphere. These are emissions from road traffic, secondary particles (mainly sulphates and nitrates), and coarse particles arising from resuspension of surface soils and dusts, sea spray and construction activity.

Recent research is focusing on the health effects of smaller size fractions, and on the significance of the number of particles rather than their mass. A standard for finer particles (PM$_{2.5}$, less than 2.5 microns) is possible when the Daughter Directive is reviewed in 2003. The DETR and European Member States have set up several sites monitoring PM$_{2.5}$ using various methods to assess the contribution of this size fraction.

The National Atmospheric Emissions Inventory (NAEI) only considers primary particles. However, there is a general reduction in concentration of secondary particles moving from a maximum in the south-east to a minimum in the north-west of the British Isles. Both UK and mainland European sources of precursor emissions (such as SO$_2$ and NOx), contribute substantially to secondary PM$_{10}$.

The Effects of PM$_{10}$′s on Health

Particles of diameter greater than about 15 µm mostly do not enter the thoracic airways but are trapped in the nose and pharynx. Particles of less than about 4 µm diameter penetrate deeply into the lung. The efficiency of deposition depends on particle size and very fine particles (20 nm or 0.02 µm) are thought to have the highest deposition efficiency in the alveolar region of the lung. A very large number of very fine particles are contained in a small mass of material. It has been demonstrated that concentrations of airborne particles once considered safe may have a significant effect on health.

Most studies are based on the statistical analysis of measured ambient levels with indices of ill health, such as daily death rates, asthmatic attacks or admission to hospital. The studies generally show a statistically significant association between day-to-day variations in mass concentrations of particles and indices of ill-health i.e. as particle concentrations increase so do ill-health indicators. To determine whether particles actually cause the ill-health effects and that other factors are not involved is difficult. Certain coherence tests can be applied by comparing the results of different studies, and by establishing dose-response relationships. Most experts regard the demonstrated associations as causal and use them in estimating the effects of particles on health. EPAQS recommended a health-based PM$_{10}$ standard of 50 µg/m$^3$ expressed as a 99th percentile of the running 24-hour mean.

The precise chemical composition of the inhaled particles may not be critical to the ill-health effects reported. Evidence suggests the effects may be a consequence of the physical properties of the particles such as shape, solubility, or acidity rather than their chemistry.
Health effects of PM$_{10}$’s are largely linked with the worsening of pre-existing conditions. There is some concern that fine particles from diesel exhaust may also have a carcinogenic effect. This may be due to air stream entrained particles carrying adsorbed carcinogens into the respiratory system. The true effects of PM$_{10}$ are difficult to determine as they are masked by other parameters often associated with different PM$_{10}$ exposure levels such as weather and lifestyle.

**UK PM$_{10}$ Emission Estimates**

The main sources of primary PM$_{10}$’s are briefly described below:

**Road Transport.** All road transport vehicles emit PM$_{10}$’s. However diesel vehicles emit a greater mass of particulate per vehicle kilometre than petrol-engined vehicles. Emissions also arise from brake and tyre wear and from the re-entrainment of dust on the road surface. The contribution from re-entrained dust is not yet included in the inventory due to the lack of a suitable estimation methodology.

**Stationary Combustion.** Domestic coal combustion has traditionally been the major source of particulate emissions in the UK and it is still a significant source in some smaller towns and villages, and in Northern Ireland. The Clean Air Acts have restricted its use in the UK and other sources are now more important nationally. Other fuels emit PM$_{10}$’s, but emissions from gas use are very small. In general, particles emitted from combustion are of a smaller size than those emitted from other sources.

**Industrial Processes.** These include bulk handling of dusty materials, construction sites, and mining and quarrying activities. These sources are all difficult to quantify due to the nature of the sources and to the lack of appropriate UK measurements. Usually a substantial fraction of the particles from these sources is larger than 10 µm but the large quantities emitted ensure that the fraction less than 10 µm is still substantial.

**Emission estimates**

Emissions of PM$_{10}$ are shown in Table 5.6 and Figure 5.3.

Emissions of PM$_{10}$ from the UK have declined dramatically since 1970. This is due mainly to the reduction in coal use. Domestic emissions have fallen from 216 tonnes (43% of the total emission) in 1970 to 28 tonnes (15%) in 1997.

There is a clear distinction between the important sources in rural and urban areas. Many of the sources do not occur inside towns and cities. While road transport accounts for only 23% of national emissions, it can account for up to 80% of primary emissions in urban areas such as London (Buckingham et al., 1997).
Emissions from electricity generation have also been declining since 1992 despite a 39% growth in the electricity generated between 1970 and 1997. This is due to the move away from coal to natural gas and nuclear power for electricity generation and to improvements in the performance of electrostatic precipitators at coal-fired power stations. The installation of flue gas desulphurisation at two coal-fired power stations has further reduced particulate emissions.

The one sector which has shown significant growth in emissions since 1970 is road transport, its contribution to total UK emissions rising from 9% in 1970 to 23% in 1997. In urban areas with little industrial activity, where public power and industrial processes do not make a significant contribution, the contribution of road transport to emissions will be even higher; for example as much as 80% of primary emissions in London. The main source of road transport emissions is exhaust from diesel engined vehicles. Emissions from diesel vehicles have been growing due to the growth in heavy duty vehicle traffic and the move towards more diesel cars, currently accounting for 11% of the car kilometres. Since around 1992, however, emissions from diesel vehicles have been decreasing due to the penetration of new diesel vehicles meeting tighter PM$_{10}$ emission regulations.

Among the non-combustion and transport sources, the major emissions are from a range of industrial processes and from mining and quarrying. The emission rates have remained fairly constant since 1970.
### Table 5.6 UK Annual Emissions of PM\textsubscript{10} (ktonnes), 1970-1997

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<tr>
<td>Waste</td>
<td>5</td>
<td>7</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>1</td>
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</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>507</td>
<td>335</td>
<td>290</td>
<td>290</td>
<td>277</td>
<td>264</td>
<td>249</td>
<td>215</td>
<td>207</td>
<td>184</td>
<td>100%</td>
</tr>
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</table>

#### Emissions by FUEL TYPE used in the above categories:

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</thead>
<tbody>
<tr>
<td>Solid</td>
<td>352</td>
<td>190</td>
<td>129</td>
<td>133</td>
<td>125</td>
<td>114</td>
<td>96</td>
<td>73</td>
<td>69</td>
<td>56</td>
<td>30%</td>
</tr>
<tr>
<td>Petroleum</td>
<td>83</td>
<td>79</td>
<td>80</td>
<td>81</td>
<td>78</td>
<td>76</td>
<td>74</td>
<td>68</td>
<td>64</td>
<td>56</td>
<td>30%</td>
</tr>
<tr>
<td>Gas</td>
<td>4</td>
<td>6</td>
<td>9</td>
<td>9</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
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<td>6%</td>
</tr>
<tr>
<td>Non-Fuel</td>
<td>68</td>
<td>60</td>
<td>72</td>
<td>67</td>
<td>65</td>
<td>65</td>
<td>69</td>
<td>63</td>
<td>61</td>
<td>61</td>
<td>33%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td>507</td>
<td>335</td>
<td>290</td>
<td>290</td>
<td>277</td>
<td>264</td>
<td>249</td>
<td>215</td>
<td>207</td>
<td>184</td>
<td>100%</td>
</tr>
</tbody>
</table>

#### Figure 5.3: Variation in Total PM\textsubscript{10} Emissions
### 5.3 Carbon Monoxide

The current air quality objective for carbon monoxide (CO) is given in Table 5.7.

**Table 5.7 Carbon monoxide Air Quality Objectives**

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Measured as</th>
<th>Date to be achieved by</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.6 mg/m³ (10 ppm)</td>
<td>Running 8-hour mean</td>
<td>December 31st 2003</td>
</tr>
</tbody>
</table>

To convert concentrations of CO between ppm and mg/m³, use the following factors:

\[
1.16 \times \text{ppm} = \text{mg/m}^3 \\
0.862 \times \text{mg/m}^3 = \text{ppm}
\]

Table 5.8 below shows how different pollutant levels translate into the DETR’s Air Pollution Information Service banding system. The low band indicates that pollution levels are less than the EPAQS running 8-hour mean objective.

**Table 5.8 CO Air Pollution Information Service Bands**

<table>
<thead>
<tr>
<th>Pollution Band</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low</strong></td>
</tr>
<tr>
<td>Less than 11.6 mg/m³</td>
</tr>
<tr>
<td>(10 ppm or less)</td>
</tr>
<tr>
<td><strong>Moderate</strong></td>
</tr>
<tr>
<td>11.6 – 16.2 mg/m³</td>
</tr>
<tr>
<td>(11 –14 ppm)</td>
</tr>
<tr>
<td><strong>High</strong></td>
</tr>
<tr>
<td>17.4 - 22.0 mg/m³</td>
</tr>
<tr>
<td>(15 –19 ppm)</td>
</tr>
<tr>
<td><strong>Very high</strong></td>
</tr>
<tr>
<td>23.2 mg/m³ or more</td>
</tr>
<tr>
<td>(20 ppm or more)</td>
</tr>
</tbody>
</table>

**Introduction**

Carbon monoxide (CO) is a colourless, odourless gas produced by the incomplete combustion of carbon based fuels. Complete combustion in the presence of sufficient oxygen leads to production of carbon dioxide, whereas if there is a slight deficiency of oxygen some carbon monoxide is formed. Inadequately ventilated gas cookers or heaters, and badly installed heaters burning gas, coal or oil may cause high levels of carbon monoxide in the home. The most important general exposures of individuals to carbon monoxide come from cigarette smoking and vehicle exhausts. The amount of carbon monoxide in the blood of a regular smoker is much greater than that which can be obtained by breathing in air from heavily polluted streets. The EPAQS standard therefore aims to limit the exposure of non-smokers to carbon monoxide in the ambient air.

Carbon monoxide is emitted from motor vehicles particularly when the engine is cold, badly tuned, idling, or moving slowly, and is at its highest level close to busy roads during rush hour periods. The gas is normally rapidly dispersed and destroyed by photochemical reaction over a period of months.
The Effects of Carbon Monoxide on Health

Carbon monoxide exerts its effect by interfering with the transport of oxygen by red blood cells. The red compound haemoglobin, contained within red blood cells, carries oxygen to the cells in the body where it is utilised in biochemical reactions. Carbon monoxide binds to haemoglobin molecules forming carboxyhaemoglobin, and therefore reduces the ability of the red blood cells to carry oxygen. Severe poisoning leads to lassitude, loss of consciousness and even death in extreme cases. Brain damage due to lack of oxygen can occur in people who recover from severe carbon monoxide poisoning.

Blood carboxyhaemoglobin levels can be measured as a percentage of the total haemoglobin, to give an indication of exposure to carbon monoxide. The amount present in the blood depends on the level and duration of exposure and on the rate and depth of breathing. When an individual is exposed to a constant level of carbon monoxide when undertaking a constant level of activity, an equilibrium carboxyhaemoglobin value is reached. Uptake from multiple sources, such as smoking and traffic, is not additive.

Levels in non-smokers at rural background locations are normally less than 1% carboxyhaemoglobin, but when exposed to 25-50 ppm carbon monoxide for several hours the level may rise to 2% or 3%. Smokers have levels of 4% to 15% depending on the type and number of cigarettes smoked. Using a mathematical relationship it can be shown that exposure to 10 ppm carbon monoxide for 8 hours at maximum activity levels, would maintain carboxyhaemoglobin levels below 2.5% in a non-smoker. This is regarded as a safe blood carboxyhaemoglobin level as effects are only detectable in susceptible individuals at between 3 and 4%.

EPAQS, in deriving a recommended health-based exposure standard, considered evidence linking carbon monoxide to possible effects on the heart and brain due to their dependency upon a high level of oxygen consumption. People with coronary heart disease have a reduced supply of blood to the heart, and often have chest pains or angina when exerting themselves increasing the risk of heart attacks. When exposed to carbon monoxide the duration of exercise needed to induce angina pain was reduced when the blood carboxyhaemoglobin reached a level of 3 to 4%.

Studies of brain function in volunteers exposed to carbon monoxide have shown subtle changes when carboxyhaemoglobin levels exceed about 5%. These changes have involved functions that require sustained attention or performance, such as hand-eye coordination. Behavioural development and impaired brain function has been observed in animals exposed to high concentrations of carbon monoxide giving rise to levels of 15 to 25% carboxyhaemoglobin.

It is likely that people with lung diseases and anaemia will also be susceptible to the effects of carbon monoxide. The developing foetus, young children and the elderly may also be at greater risk.
UK CO Emission Estimates

The main source of carbon monoxide in the UK is road transport, which in 1997 accounted for almost 75% of the UK total. Of this road transport emission, the predominant source is petrol vehicles, which accounts for 71% of the UK total and 95% of the road transport emission. Figure 5.4 shows that emissions from road transport fell only slightly between 1970 and 1990 but in recent years have declined more significantly. This is due primarily to the increased use of catalytic converters and to a lesser extent to fuel switching from petrol cars to diesel cars. The emissions from off-road sources includes portable generators, fork lift trucks, lawnmowers and cement mixers. The estimation of emissions from such machinery is very uncertain since it is based on estimates of equipment population and annual usage time.

Emissions from the domestic sector have decreased by 80% since 1970 due to the decline in the use of solid fuels in favour of gas and electricity. Power stations account for only 1% of total UK emissions. The sudden decline in emissions from the agricultural sector reflects the banning of straw and stubble burning in 1993 in England and Wales (see land use change, table 5.9).

Overall there has been a 30% reduction in carbon monoxide emissions between 1990 and 1997 (7566 to 5090 ktonnes).
### Table 5.9 UK Annual Emissions of Carbon Monoxide (kt), 1970-1997

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<td>Public Power</td>
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<td>121</td>
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<td>113</td>
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<td>106</td>
<td>104</td>
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<td>Petroleum Refining Plants</td>
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<td>6</td>
<td>6</td>
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<td>Other Comb. &amp; Trans.</td>
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<td>15</td>
<td>15</td>
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<td>Residential Plant</td>
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<td>Comm/Public/Agri Comb.</td>
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<td>22</td>
<td>22</td>
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<td>21</td>
<td>20</td>
<td>19</td>
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<td><strong>Combustion in Industry</strong></td>
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<td>Iron &amp; Steel Combustion</td>
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<td>80</td>
<td>83</td>
<td>86</td>
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<td>4731</td>
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<td>Off-Road Sources</td>
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<td>347</td>
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<td>Waste</td>
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<td>Land Use Change</td>
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<td><strong>Total</strong></td>
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<tr>
<td>Solid</td>
<td>1545</td>
<td>725</td>
<td>477</td>
<td>496</td>
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<td>416</td>
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<td>Petroleum</td>
<td>6542</td>
<td>6374</td>
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<td>6095</td>
<td>5793</td>
<td>5425</td>
<td>5112</td>
<td>4776</td>
<td>4504</td>
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<td>Gas</td>
<td>25</td>
<td>24</td>
<td>30</td>
<td>30</td>
<td>33</td>
<td>40</td>
<td>44</td>
<td>47</td>
<td>50</td>
<td>46</td>
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<tr>
<td>Non-Fuel</td>
<td>741</td>
<td>886</td>
<td>839</td>
<td>764</td>
<td>686</td>
<td>530</td>
<td>553</td>
<td>551</td>
<td>567</td>
<td>575</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>8854</td>
<td>8008</td>
<td>7566</td>
<td>7386</td>
<td>7072</td>
<td>6547</td>
<td>6126</td>
<td>5727</td>
<td>5475</td>
<td>5090</td>
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Figure 5.4: Variation in Total Carbon Monoxide Emissions
6 AIR QUALITY MONITORING DATA

Air monitoring methodologies can be divided into four main types covering a wide range of costs and performance levels.

1. Passive sampling methods using diffusion tubes provide a simple and cheap method of initially screening an area to give an indication of average pollution concentrations. They are used extensively in Milton Keynes for monitoring monthly average nitrogen dioxide levels at many locations throughout the Borough. Diffusion tubes are prepared and analysed by the Environmental Protection Team at the Civic Offices, Central Milton Keynes. The National Environmental Technology Centre (NETCEN) at AEA Technology plc provides a quality control and assurance scheme for the diffusion tube procedures.

2. The sulphur dioxide 8-port bubbler apparatus in Rickley Park Bletchley is an example of an active (semi-automatic) sampling method. Sulphur dioxide is collected by passing an air sample into a bottle ("bubbler") containing hydrogen peroxide solution, which is then analysed in the laboratory to give a daily average SO\(_2\) concentration.

3. Remote optical/long path analysers use a spectroscopic technique to make real-time measurements of a range of pollutants between a light source and detector. They can be used for monitoring NO\(_2\) and SO\(_2\) but not for particles. The analysers are expensive, and the measurements obtained are not directly comparable with automatic point monitoring analysers as used by the Council.

4. Automatic real-time point analyser methods provide accurate high-resolution data essential for a Third Stage review and assessment. The Council has automatic analysers for oxides of nitrogen, sulphur dioxide, particulate matter and carbon monoxide. Samples of air are analysed continuously, in real-time and data can be viewed and downloaded remotely. Portable automatic analysers using electrochemical or solid state sensor based systems are available but they are of low sensitivity and only suitable for identifying hotspots. An Osiris portable particulate monitor is used by the Council for this function.

Accurate automatic samplers provide short-term average data, which is necessary to demonstrate compliance with the relevant standards and objectives, and validate modelling data. The most sophisticated monitoring stations are those that are part of the National Automatic Urban Network (AUN) operated on behalf of the Department of the Environment, Transport and Regions. Raw data from these stations can be retrieved from the DETR home page on the internet and is updated every four hours. The instruments are maintained and calibrated to high standards and while the raw data is reasonably accurate, it has to be validated and ratified to take into account calibration errors and other anomalies.
Continuous Automatic Monitoring in Milton Keynes

Milton Keynes Council has three continuous automatic monitoring air quality stations, supplied by Horiba Instruments of Northampton. There is a fixed monitoring station located within the walled garden at the rear of the Civic Offices, parallel with the pavement of North Eighth Street. (see Figure 6.1). The site is classed as an urban centre (U3) location representative of typical population exposure in the city centre. The Council also has two mobile air quality stations, which can be moved to various locations throughout the borough. The mobile stations are used to assess possible air pollution hotspots and collect data for a few months. Ideally, for direct comparison with the Strategy objectives, a minimum of one complete year of data is required. Since coming on-line in October 1998, mobile station “A” has been sited in six locations throughout the Borough, as detailed in table 6.3. An additional mobile station “B” became operational in August 2000 and is currently sited on Wolverton Road, Newport Pagnell.

The stations contain NETCEN type-tested and approved analysers, as used in national networks, housed in secure air-conditioned containers to maintain the correct operating temperature range. Most functions of the air quality stations are automatic or can be operated by remote communication via modem, usually from the air quality monitoring computer at the Civic Offices. Data are downloaded at least twice daily, and gas analysers are check calibrated automatically every 3 days using a gas mixture of known concentration to ensure accuracy of data.

A full service by the manufacturer is undertaken every 6 months and the service includes a verification of the calibration gas concentration using a traceable standard. After correction has been made to the data set for any calibration errors, and other relevant factors, the data are usable for comparison with the objectives of the Strategy. The UK Automatic Network Site Operator’s Manual, produced by NETCEN, is used as an operational guide for the automatic monitoring stations.

Description of Analysers used in Automatic Monitoring Stations in Milton Keynes

**Particulate Matter.** PM$_{10}$ is measured by using a Tapered Element Oscillating Microbalance (TEOM) Series 1400a, manufactured by Rupprecht and Patashnick. The TEOM consists of a filter cartridge located on top of a hollow tapered crystal element. The element is clamped at one end and free to vibrate at the other. The sample air stream is drawn through the filter and the through the element. A mass flow controller unit maintains constant flow through the system. The crystal element vibrates at its natural frequency and as particles are deposited on the filter the frequency of vibration decreases. The change in frequency is proportional to the mass deposited on the filter.

**Oxides of Nitrogen.** Chemiluminescent analysers are used to detect oxides of nitrogen. The method is based on the chemiluminescent energy emitted when nitric oxide is reacted with ozone in an evacuated chamber to form chemiluminescent nitrogen dioxide. A photomultiplier tube (PMT) and amplifier convert the emitted light signal into a voltage. The strength of the output voltage is proportional to the concentration of NO in the reaction.
chamber. The incoming air sample is divided into two streams. One stream passes directly into the reaction chamber to measure the NO concentration. The other stream first passes through a heated molybdenum catalyst which reduces NO₂ to NO; the photomultiplier output is then proportional to total oxides of nitrogen (NOₓ). The NO₂ concentration in the ambient sample is determined from the NOₓ and NO voltages by subtraction.

**Sulphur Dioxide.** The SO₂ analysers work on the principle of ultra-violet fluorescence (UVF). SO₂ molecules are excited to higher but unstable energy states by UV radiation at 212 nm. These energy states decay, causing an emission of secondary radiation (fluorescence) with an intensity proportional to the concentration of SO₂ in the sample.

Ambient air is drawn into the reaction chamber via a hydrocarbon kicker, which removes the interference effects of aromatic hydrocarbons. The UV light passes into the reaction cell through a chopper wheel, producing a stable low noise output. A photomultiplier tube (PMT) and amplifier convert the emitted fluorescent light signal into a voltage. The PMT and photodetector outputs produce a compensated voltage proportional to the SO₂ concentration.

**Carbon Monoxide.** Non-dispersive infra-red absorption analysers, with cross-flow modulation, are used to detect carbon monoxide. The concentration of carbon monoxide is measured by the absorption of infra-red radiation at 4.5-4.9 mm wavelength. Differences in infra-red absorption between ambient air and reference gas (air with all CO removed) cause a metallic membrane in the detector to move back and forth in accordance with the alternating gas flow and CO concentration. An infra-red detector and amplification system produce output voltages proportional to the CO concentration.

Table 6.1 details the analysers in the air quality monitoring stations and the dates on which they became operational. The locations where the mobile air quality station has been sited are shown in figures 6.1 to 6.4.
Table 6.1 Automatic Monitoring Station Analysers

<table>
<thead>
<tr>
<th>Analyser</th>
<th>Principle of Measurement</th>
<th>Date Installed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Static</td>
</tr>
<tr>
<td><strong>NO₂ Monitor</strong></td>
<td>Chemiluminescence (CLD)</td>
<td>21-May-98</td>
</tr>
<tr>
<td><strong>Particulate (PM₁₀) Monitor</strong></td>
<td>TEOM</td>
<td>21-May-98</td>
</tr>
<tr>
<td><strong>SO₂ Monitor</strong></td>
<td>UV Fluorescence (UVF)</td>
<td>04-Feb-99</td>
</tr>
<tr>
<td><strong>CO Monitor</strong></td>
<td>Non-dispersive infrared absorption technology (NDIR)</td>
<td>06-Jul-00</td>
</tr>
</tbody>
</table>

Figure 6.1: Fixed Air Quality Station
Civic Offices, CMK
Figure 6.2: Mobile locations
▲ Market Place and High Street
Olney

Figure 6.3: Mobile Locations
▲ Miles Close and Wolverton Road,
Newport Pagnell
Figure 6.4: Mobile Location
△ Lovat School, Avon Close, Newport Pagnell

Figure 6.5: Mobile Location
△ Western Road, Bletchley
6.1 Nitrogen Dioxide Monitoring Data

The results obtained from the automatic air quality stations are summarised in tables 6.2 and 6.3, and represented graphically in figures 6.6 to 6.23.

STATIC SITE, Civic Offices, CMK:

The annual average NO$_2$ concentration for 1999 was 27.4 µg/m$^3$ compared to the objective of 40 µg/m$^3$. There have been no exceedances of the hourly objective of 200 µg/m$^3$ since the monitoring station became operational in June 1998. However, the 99.8th percentile value of hourly means has increased up to the present date although the increase is not reflected in the monitoring period average concentration. The collected data are expressed graphically in Figures 6.6 to 6.8.

MOBILE LOCATIONS

Market Place Olney:

An average NO$_2$ concentration of 27.9 µg/m$^3$ was measured over the 24-day monitoring period. There were no exceedances of the short-term hourly objective, even on busy market days.

20 High Street, Olney:

At this kerbside site an average NO$_2$ concentration of 38.8 µg/m$^3$ was measured over the 3-month monitoring period, with no exceedances of the hourly objective. Higher concentrations are expected at kerbside sites, especially during the winter months. There is also a “canyon effect” caused by buildings either side of the road, which restricts the dispersion and dilution rate of air pollutants.

3, Miles Close, Blakelands:

This site is at the end of a cul-de-sac approximately 65 metres from the edge of the M1 motorway. An average NO$_2$ concentration of 29.9 µg/m$^3$ was measured over the 3-month monitoring period, with no exceedances of the hourly objective. This result was lower than expected, possibly because of the prevailing south-westerly wind, and the elevated position of the motorway.

Wolverton Road, Newport Pagnell:

The monitoring site is on the grass verge 3.6 metres from the Wolverton Road near the entrance to Walnut Close, and 145 metres from the edge of the M1 motorway. The average NO$_2$ concentration was 37.1 µg/m$^3$ measured over a 6-month monitoring period, and there were no exceedances of the hourly objective. The monitoring period did not include the winter months where pollutant levels are generally higher.
Lovat School, Newport Pagnell:

The school is approximately 1.3 kilometres from the M1 on the outskirts of a residential area. The average NO₂ concentration was 28.5 µg/m³ measured over a 4-month monitoring period during the winter months, and there were no exceedances of the hourly objective. The concentrations recorded were representative of background levels.

Western Road, Bletchley:

The site is at the end of Western Road on the grass verge adjacent to No.165, at the junction with North Street and Princes Way. The average NO₂ concentration was 24.7 µg/m³ measured over a 3-month monitoring period and there were no exceedances of the hourly objective.
Table 6.2: Static Air Quality Station – NO₂ Concentration Summary (µg/m³)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Average NO₂ Concentration</td>
<td>28.2</td>
<td>27.4</td>
<td>28.1</td>
</tr>
<tr>
<td>Number of hourly NO₂ exceedances</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>99.8th Percentile of 1 hour mean concentrations</td>
<td>83.2</td>
<td>96.9</td>
<td>110.2</td>
</tr>
</tbody>
</table>

Table 6.3: Mobile Air Quality Station – NO₂ Concentration Summary (µg/m³)

<table>
<thead>
<tr>
<th>Location</th>
<th>Market Place, Olney</th>
<th>Outside 20 High Street, Olney</th>
<th>Miles Close, Blakelands</th>
<th>Wolverton Road, Newport Pagnell</th>
<th>Lovat School, Newport Pagnell</th>
<th>Western Road, Bletchley</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site class</td>
<td>Roadside</td>
<td>Kerbside</td>
<td>Urban Centre</td>
<td>Roadside</td>
<td>Urban Background</td>
<td>Urban Background</td>
</tr>
<tr>
<td>Dates on site</td>
<td>19-Oct-98 to 11-Nov-98</td>
<td>11-Nov-98 to 11-Feb-99</td>
<td>11-Feb-99 to 05-May-99</td>
<td>05-May-99 to 29-Nov-99</td>
<td>29-Nov-99 to 22-Mar-00</td>
<td>22-Mar-00 to 18-Jun-00</td>
</tr>
<tr>
<td>Average NO₂ Concentration</td>
<td>27.9</td>
<td>37.8</td>
<td>29.9</td>
<td>37.1</td>
<td>28.5</td>
<td>24.7</td>
</tr>
<tr>
<td>Number of hourly NO₂ exceedances</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>99.8th Percentile of 1-hour means</td>
<td>80.4</td>
<td>78.8</td>
<td>113.1</td>
<td>126.9</td>
<td>88.5</td>
<td>109</td>
</tr>
</tbody>
</table>
Civic Offices, Central Milton Keynes - 1998  (May – December)

NO\(_2\) 1 hour averages

Figure 6.6
Figure 6.7

Civic Offices, Central Milton Keynes - 1999
NO₂ 1 hour averages

Date
01.01.1999
02.01.1999
03.01.1999
04.01.1999
05.01.1999
06.01.1999

Concentration µg/m³
0.00
250.00

Target 200 µg/m³
200.00
150.00
100.00
50.00
0.00

NO₂ µg/m³
Figure 6.8

Civic Offices, Central Milton Keynes - 2000 (January – June)

NO$_2$ 1 hour averages

Date

Concentration µg/m$^3$

0.00

50.00

100.00

150.00

200.00

250.00

01.01.2000
06.01.2000
12.01.2000
15.01.2000
18.01.2000
22.01.2000
25.01.2000
01.02.2000
04.02.2000
08.02.2000
11.02.2000
15.02.2000
18.02.2000
22.02.2000
25.02.2000
01.03.2000
04.03.2000
08.03.2000
11.03.2000
15.03.2000
18.03.2000
22.03.2000
25.03.2000
01.04.2000
04.04.2000
08.04.2000
11.04.2000
15.04.2000
18.04.2000
22.04.2000
25.04.2000
01.05.2000
04.05.2000
08.05.2000
11.05.2000
15.05.2000
18.05.2000
22.05.2000
25.05.2000
01.06.2000
04.06.2000
08.06.2000
11.06.2000
15.06.2000
18.06.2000
22.06.2000
25.06.2000
01.07.2000
04.07.2000
08.07.2000
11.07.2000
15.07.2000
18.07.2000
22.07.2000
25.07.2000
01.08.2000
04.08.2000
08.08.2000
11.08.2000
15.08.2000
18.08.2000
22.08.2000
25.08.2000
01.09.2000
04.09.2000
08.09.2000
11.09.2000
15.09.2000
18.09.2000
22.09.2000
25.09.2000
01.10.2000
04.10.2000
08.10.2000
11.10.2000
15.10.2000
18.10.2000
22.10.2000
25.10.2000
01.11.2000
04.11.2000
08.11.2000
11.11.2000
15.11.2000
18.11.2000
22.11.2000
25.11.2000
01.12.2000
04.12.2000
08.12.2000
11.12.2000
15.12.2000
18.12.2000
22.12.2000
25.12.2000

Figure 6.8 (January – June)
Miles Close, Blakelands - 11th February 1999 to 5th May 1999

NO₂ 1 hour averages

Figure 6.11
Wolverton Road, Newport Pagnell - 5th May 1999 to 29th November 1999
NO₂ 1 hour averages

Figure 6.12
Western Road, Bletchley - 22nd March 2000 to 18th June 2000
NO₂ 1 hour averages

Figure 6.14
6.2 Particulate Matter Monitoring Data

Monitoring of PM$_{10}$ in the UK is based upon the TEOM continuous analyser and this instrument is used in the Milton Keynes automatic monitoring stations. However, the air quality objectives are based upon measurements carried out using the European transfer gravimetric method or equivalent which gives a single 24-hour total PM$_{10}$ reading. The TEOM filter is maintained at a temperature of 50ºC in order to minimise errors associated with the evaporation and condensation of water vapour, but can lead to the loss of more volatile particulates. The quality of data from gravimetric samplers can also be adversely affected if considerable care and attention is not given to the processes of filter handling, pre and post-conditioning, and weighing. A difference in readings has been identified between co-located TEOM and gravimetric analysers.

The recently published Airborne Particles Expert Group (APEG) report concluded that at concentrations around 50 µg/m$^3$ the TEOM tends to under-read compared with a gravimetric sampler by between 15 and 30%. It is therefore necessary to apply a correction factor when assessing TEOM measured concentrations against the objectives. A conservative approach is recommended by both APEG and the DETR (Pollutant Specific Guidance TG4) to increase measured TEOM readings by 30%. A TEOM reading of 20 µg/m$^3$ is expressed as $20 \times 1.3 = 26$ µg/m$^3$, gravimetric.

All monitoring data in this report are expressed as µg/m$^3$, **gravimetric**.

RESULTS

The results obtained from the automatic air quality stations are summarised in tables 6.4 and 6.5, and represented graphically in figures 6.15 to 6.23. All sites monitored were well within the objectives of 40 µg/m$^3$ as an annual mean, and 50 µg/m$^3$ as a fixed 24-hour mean not to be exceeded more than 35 times a year.

**Static site, Civic Offices:**

The annual average concentration of PM$_{10}$ at the Civic Office site is approximately 21 µg/m$^3$, compared with the annual objective of 40 µg/m$^3$. Daily exceedances of the 24-hour objective are rare, there having been only six daily exceedances since monitoring began in June 1998, (see table 6.4 and figures 6.15, 6.16, 6.17).

**MOBILE LOCATIONS**

**Market Place Olney:**

An average PM$_{10}$ concentration of 18.8 µg/m$^3$ was measured over the 24-day monitoring period. There were no exceedances of the 24-hour objective.

**20 High Street, Olney:**

At this kerbside site an average PM$_{10}$ concentration of 23.8 µg/m$^3$ was measured over the
3-month monitoring period. The corresponding value recorded from the static site at the Civic Offices for the same period, was 20.9 µg/m³. Particulate concentrations are generally elevated at kerbside sites where the emission source is closest to the TEOM inlet. The 24-hour objective was exceeded on 23rd November 1998 with a recorded value of 51.8 µg/m³.

3, Miles Close, Blakelands:

An average PM₁₀ concentration of 20.8 µg/m³ was measured over the 3-month monitoring period, with a 24-hour exceedance on the 1st April 1999. A similar exceedance was measured at the static site on this day.

Wolverton Road, Newport Pagnell:

The average PM₁₀ concentration was 23.0 µg/m³ measured over a 6-month monitoring period, with a 24-hour exceedance on the 11th September 1999. The static site also exceeded the objective on this day.

Lovat School, Newport Pagnell:

The average PM₁₀ concentration was low at 16.1 µg/m³ measured over a 4-month monitoring period during the winter months, and there were no exceedances of the 24-hour objective. The concentrations recorded were representative of background levels.

Western Road, Bletchley:

The average PM₁₀ concentration was 18.7 µg/m³ measured over a 3-month monitoring period and there were no exceedances of the 24-hour objective.

PM₁₀ emissions (g/km) from road traffic are highest at slower speeds and the increase is most significant for HGV’s.

Future trends are likely to show a decrease in ambient PM₁₀ levels. A variety of measures for reducing PM₁₀ emissions from road traffic has already been introduced. The UKNAQS expects a reduction in PM₁₀ emissions from vehicles of almost 40% by the year 2005 based on 1995 figures.
Table 6.4: Static Air Quality Station – PM$_{10}$ Concentration Summary (µg/m$^3$ gravimetric)

<table>
<thead>
<tr>
<th>Time period</th>
<th>Average PM$_{10}$ Concentration</th>
<th>Number of daily PM$_{10}$ exceedances</th>
<th>PM$_{10}$ 90th Percentile of 24 hour means</th>
</tr>
</thead>
<tbody>
<tr>
<td>1$^{\text{st}}$ June 1998 to 31$^{\text{st}}$ December 1998</td>
<td>20.7</td>
<td>2</td>
<td>31.4</td>
</tr>
<tr>
<td>1$^{\text{st}}$ January 1999 to 31$^{\text{st}}$ December 1999</td>
<td>21.1</td>
<td>2</td>
<td>32.9</td>
</tr>
<tr>
<td>1$^{\text{st}}$ January 2000 to 18$^{\text{th}}$ June 2000</td>
<td>21.2</td>
<td>2</td>
<td>32.6</td>
</tr>
</tbody>
</table>

Table 6.5: Mobile Air Quality Station – PM$_{10}$ Concentration Summary (µg/m$^3$ gravimetric)

<table>
<thead>
<tr>
<th>Location</th>
<th>Site class</th>
<th>Dates on site</th>
<th>Average PM$_{10}$ Concentration</th>
<th>Number of daily PM$_{10}$ exceedances</th>
<th>PM$_{10}$ 90th Percentile of 24 hour means</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Place, Olney</td>
<td>Roadside</td>
<td>19-Oct-98 to 11-Nov-98</td>
<td>18.8</td>
<td>0</td>
<td>24.2</td>
</tr>
<tr>
<td>Outside 20 High Street, Olney</td>
<td>Kerbside</td>
<td>11-Nov-98 to 11-Feb-99</td>
<td>23.8</td>
<td>1</td>
<td>35.6</td>
</tr>
<tr>
<td>Miles Close, Blakelands</td>
<td>Urban Background</td>
<td>11-Feb-99 to 05-May-99</td>
<td>20.8</td>
<td>1</td>
<td>31.3</td>
</tr>
<tr>
<td>Wolverton Road, Newport Pagnell</td>
<td>Roadside</td>
<td>05-May-99 to 29-Nov-99</td>
<td>23.0</td>
<td>1</td>
<td>32.7</td>
</tr>
<tr>
<td>Lovat School, Newport Pagnell</td>
<td>Urban Background</td>
<td>29-Nov-99 to 22-Mar-00</td>
<td>16.1</td>
<td>0</td>
<td>23.9</td>
</tr>
<tr>
<td>Western Road, Bletchley</td>
<td>Urban Background</td>
<td>22-Mar-00 to 18-Jun-00</td>
<td>18.7</td>
<td>0</td>
<td>32.2</td>
</tr>
</tbody>
</table>
Civic Offices, Central Milton Keynes 1998 (May – December)
PM10 (Gravimetric) 24 hour averages

Figure 6.15
Civic Offices, Central Milton Keynes - 1999
PM10 (Gravimetric) 24 hour averages

Figure 6.16
Civic Offices, Milton Keynes - 2000 (January – June)
PM10 (Gravimetric) 24 hour averages

Figure 6.17
Market Square, Olney - 19th October 1998 to 11th November 1998
PM\textsubscript{10} (Gravimetric) 24 hour averages

Figure 6.18

<table>
<thead>
<tr>
<th>Date</th>
<th>Concentration µg/m\textsuperscript{3}</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.10.98</td>
<td></td>
</tr>
<tr>
<td>20.10.98</td>
<td></td>
</tr>
<tr>
<td>21.10.98</td>
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<td>22.10.98</td>
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<td>23.10.98</td>
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<td>24.10.98</td>
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<td>25.10.98</td>
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<td>26.10.98</td>
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<td>27.10.98</td>
<td></td>
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<tr>
<td>28.10.98</td>
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<td>29.10.98</td>
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<td>30.10.98</td>
<td></td>
</tr>
<tr>
<td>31.10.98</td>
<td></td>
</tr>
<tr>
<td>01.11.98</td>
<td></td>
</tr>
<tr>
<td>02.11.98</td>
<td></td>
</tr>
<tr>
<td>03.11.98</td>
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<tr>
<td>04.11.98</td>
<td></td>
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<td>05.11.98</td>
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<tr>
<td>06.11.98</td>
<td></td>
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<tr>
<td>07.11.98</td>
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</tr>
<tr>
<td>08.11.98</td>
<td></td>
</tr>
<tr>
<td>09.11.98</td>
<td></td>
</tr>
<tr>
<td>10.11.98</td>
<td></td>
</tr>
<tr>
<td>11.11.98</td>
<td></td>
</tr>
</tbody>
</table>
High Street, Olney - 11th November 1998 to 11th February 1999
PM$_{10}$ (Gravimetric) 24 hour averages

Figure 6.19
Miles Close, Blakelands - 11th February 1999 to 5th May 1999
PM$_{10}$ (Gravimetric) 24 hour averages

Figure 6.20
Wolverton Road, Newport Pagnell - 5th May 1999 to 29th November 1999
PM$_{10}$ (Gravimetric) 24 hour averages

Figure 6.21
Lovat School, Newport Pagnell - 29th November 1999 to 22nd March 2000

PM$_{10}$ (Gravimetric) 24 hour averages

Figure 6.22
Western Road, Bletchley - 22nd March 2000 to 26th June 2000
PM$_{10}$ (Gravimetric) 24 hour averages

Figure 6.23
6.3 Carbon Monoxide Monitoring Data

Measurements of carbon monoxide levels have been available on a national scale for many years. Carbon monoxide is currently monitored at a total of 65 Automatic Urban Network (AUN) sites throughout the United Kingdom, using infra-red continuous monitors. Given that motor vehicles are the primary source of carbon monoxide, it is expected that the variation of the pollutant over a 24-hour period is likely to mirror local traffic patterns. This effect has been widely confirmed particularly where carbon monoxide is being monitored close to heavily trafficked roads.

Seasonal variations of carbon monoxide levels tend to produce higher concentrations over the winter periods than those of the summer due to the existence in the summer months of meteorological conditions more favourable to dispersion. This effect is enhanced by the influence of cold start emissions.

Even on a national scale the monitoring of carbon monoxide has not been established for a long enough period to accurately identify annual trends. The UKNAQS reports that national trends indicate a decline in levels of carbon monoxide since 1989 by around 10-50% depending on the location of the monitoring site. Further emission control measures are set to be introduced in an attempt to reduce carbon monoxide emissions from road vehicles, (i.e. a 48% reduction by the year 2005 based on 1995 data). This will make any exceedance of the carbon monoxide air quality objectives very unlikely.

Carbon monoxide was not monitored in Milton Keynes at the time the third stage assessment was undertaken. In July and August 2000, infra-red carbon monoxide analysers were added to the air quality stations. For the purposes of this report, data from DETR AUN stations shown in Table 6.6 have been used to assess whether there may be exceedances of the 2003 objective. The 1998 measured concentrations at these sites were well below the 8-hour running mean air quality objective of 11.6 mg/m³.

Table 6.6

<table>
<thead>
<tr>
<th>Location</th>
<th>Maximum 8 hour mean (mgm⁻³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oxford Centre</td>
<td>7.3</td>
</tr>
<tr>
<td>Leicester Centre</td>
<td>4.3</td>
</tr>
<tr>
<td>Birmingham East</td>
<td>5.8</td>
</tr>
</tbody>
</table>

Early indications from the continuous monitoring analysers are that CO concentrations in Milton Keynes are low and are unlikely to exceed the objective.
7 MODELLING METHODOLOGY

The AAQuiRE 2000 regional air quality model was used to predict nitrogen dioxide, PM$_{10}$ and carbon monoxide concentrations in the base year (1999) and a future year that corresponds with the objectives in the Air Quality (England) Regulations 2000. The AAQuiRE regional dispersion model, which was developed by CES and has been used throughout the world for the past 8 years, uses dispersion algorithms that have been independently and extensively validated. A description of AAQuiRE and the stages required in any detailed modelling study are given in Appendix C.

There are 4 main categories of air pollutant sources including road traffic, industrial processes (i.e. Part A and B's), diffuse sources (e.g. domestic heating), and mobile sources (e.g. airports, rail and shipping). This information was provided by the Milton Keynes traffic model and by the Environmental Health Division’s Environmental Protection Team.

7.1 Road Transport Emissions Data

Road transport represents the major source of pollution in the study area and it was therefore imperative that the emissions data were as accurate as possible. Speed related emission factors were provided by the London Research Centre (LRC), based on models produced by NETCEN and Transport Research Laboratory (TRL), and were used for the base case (1996). The figures for future years (i.e. 2003/4/5) were derived from the 1999 speed related emission factors using a year correction factor. This factor was determined from emissions data provided by the Highways Agency for the Heathrow Airport Terminal 5 (T5) Public Inquiry.

The vehicle fleet was classified into four categories of vehicles: petrol-engined vehicles without catalysts, petrol-engined vehicles with catalysts, diesel-engined light duty vehicles (LDV) and heavy duty vehicles (HDV). The vehicle fleet composition was different for each of the years assessed. This was due to an increase in the number of petrol-engined vehicles fitted with catalysts and an increase in the proportion of diesel LDVs, in later years.

The particulate emission rates include all sizes of particulate. A small proportion of the particles emitted from the exhaust may be larger than 10 µm. As a worst case, it is assumed that all of the exhaust particles are PM$_{10}$. PM$_{10}$ will also be produced by vehicles from tyre wear, brake linings and due to resuspended dust from the road. The PM$_{10}$ contribution from these three sources was estimated to be 0.01 g/km for LDVs and 0.02 g/km for HDVs.

Emissions of some pollutants are higher when the engine is cold. Cars take about 3 minutes or 1.6 km before the engine is hot. This was accounted for by using a variable vehicle composition profile for each road. Enhancement of pollutant emissions due to cold starts is given in Table 7.1.
Table 7.1: Increased Emissions from Cold Cars

<table>
<thead>
<tr>
<th>LDV Category</th>
<th>NO\textsubscript{x}</th>
<th>CO</th>
<th>PM\textsubscript{10}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non catalyst petrol</td>
<td>1.0</td>
<td>1.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Catalyst petrol</td>
<td>1.3</td>
<td>9.6</td>
<td>1.0</td>
</tr>
<tr>
<td>Diesel</td>
<td>1.2</td>
<td>1.6</td>
<td>2.0</td>
</tr>
</tbody>
</table>

e.g. a petrol-engined LDV with catalyst, emits 9.6 times more CO and 1.3 times more NO\textsubscript{x} when cold.

It is likely that a small proportion of catalysts in the LDV fleet will not be functioning at any one time. This proportion was taken to be 3% of the catalyst vehicles. The emissions from failed catalyst vehicles were taken to be the same as those from non-catalyst vehicles.

7.2 Traffic and Industrial Data

Road traffic flow, speed and HGV proportions were obtained from Milton Keynes Council’s Transport Policy Section based on information collected from monitoring sites detailed in Figure 7.2. The data collected from these sites were input into the validated traffic model, Saturn, to obtain predicted 2005 traffic levels. The 24-hour traffic profile used for this study is shown in Figure 6.1. Modelling of emissions from traffic was only required for nitrogen dioxide and PM\textsubscript{10}, as the Stage 1 review and assessment established that traffic emissions from other pollutants are not significant. However, predictions of carbon monoxide concentrations were also made due to public concern and interest.

The only potentially significant source of pollution from industry was the RMC roadstone coating plant in Bletchley. Emissions of nitrogen dioxide were modelled using AAQuIRE while the smaller Part B processes were incorporated into the background concentration.
Figure 7.2 Traffic Monitoring Locations
7.3 Background Concentrations

Dispersion models only directly predict concentrations of pollutants arising from the sources which have been input to them. A large number of small sources of air pollutants exist which individually may not be significant but collectively, over a large area, need to be considered. Pollutants may also originate from outside of the immediate study area. These sources are accounted for by including background contributions, which are given in Table 7.2. These were based on data from the National Air Quality Archive (see Appendix B) and local monitoring data. Carbon monoxide and oxides of nitrogen background concentrations for the year of their objectives, were determined from the 1999 base case value by applying the correction factors outlined in ‘Review and Assessment: Pollutant Specific Guidance’, LAQM.TG4(00), Boxes 2.2 and 6.2, respectively.

The annual mean NO\textsubscript{x} value measured at the Civic Offices automatic monitoring site in 1999 was 22.5 µg/m\textsuperscript{3}, which compares favourably with the National Air Quality Archive background map value.

PM\textsubscript{10} background concentrations were determined using the methodology given in ‘Assistance with Review and Assessment of PM\textsubscript{10} concentrations in relation to the proposed EU Stage 1 Limit Values’ combined with information given in the National Air Quality Archive. The background included contributions from secondary particles, coarse particles and local sources of particles.

As the local authority has some control over emissions of NO\textsubscript{x} but little or no control over the atmospheric oxidants that oxidise the NO to NO\textsubscript{2}, it is more appropriate to review NO\textsubscript{2} by first reviewing NO\textsubscript{x}. It is for this reason that a NO\textsubscript{x} background is applied to the modelled NO\textsubscript{x} concentration before a variable NO\textsubscript{2}/NO\textsubscript{x} is applied. Large changes to predicted NO\textsubscript{x} concentrations may only result in a small change to the NO\textsubscript{2} concentration (see Appendix D).

<table>
<thead>
<tr>
<th>Table 7.2: Pollutant Background Concentrations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base Case (1999)</td>
</tr>
<tr>
<td>Nitrogen Oxides, NO\textsubscript{x} (µg/m\textsuperscript{3})</td>
</tr>
<tr>
<td>Primary PM\textsubscript{10} (µg/m\textsuperscript{3})</td>
</tr>
<tr>
<td>Secondary PM\textsubscript{10} (µg/m\textsuperscript{3})</td>
</tr>
<tr>
<td>Carbon Monoxide (mg/m\textsuperscript{3})</td>
</tr>
</tbody>
</table>

7.4 Meteorological data

The Meteorological Office recommended that CES consultants use data obtained from Stansted Airport observing station, over a five-year period (1990-1995), as the most appropriate for the modelling study. Separate files were created for modelling the industrial sources and the mobile sources. Hourly sequential data was used for the industrial sources.
while summarised data was used for the mobile sources. The summarised data consisted of the frequencies of occurrence of wind speed (0, 1, 2, 3, 4-7, 8-16, 17+ knots), wind direction (10° resolution) and Pasquill stability classes, which categorises the stability of the atmosphere from A (very unstable) through D (neutral) to F (stable).

The meteorological data was used to produce a wind/stability rose. The rose consisted of 12 wind direction sectors of 30°, 5 wind speed bands and 3 stability classes. The windrose in Figure 7.3 shows the resulting data used for the modelling.

Calm winds were distributed evenly between the wind directions sectors in the 1-knot category. The stability classes used were C, D and E where all of the unstable classes were grouped in C and all of the stable in E.

**Figure 7.3: Windrose used for Stage 3 Review and Assessment**
8 PREDICTED LEVELS

8.1 Nitrogen Dioxide

This assessment considers two air quality objectives for nitrogen dioxide: the 99.8\textsuperscript{th} percentile of hourly means of 200 µg/m\textsuperscript{3} and the annual average of hourly means of 40 µg/m\textsuperscript{3}.

Figures 1.1.a/b and 1.2.a/b (contour maps) show the predicted annual average and 99.8\textsuperscript{th} percentile of hourly mean concentrations for the base case (1999) and the year 2005. The highest concentrations clearly follow the major roads, showing that the majority of the emissions are transport related. Figure 1.1.a indicates that the annual average objective is exceeded in 1999 at a large number of residential properties, within about 85 metres of the edge of M1 motorway.

Figure 1.2.a shows that the predicted annual average concentrations in the year 2005 exceed the objective close to the M1 motorway. In order to examine potential exceedances in more detail, larger scale contour plots were produced so that population exposure could also be considered. These include plots of Newport Pagnell, Olney and Central Milton Keynes. Emphasis has been placed on non-occupational, near ground level outdoor locations where the public might be exposed for a substantial part of the day.

The highest predicted roadside concentration in the Borough in 2005 is 130 µg/m\textsuperscript{3}, well within the hourly objective of 200 µg/m\textsuperscript{3}. The larger scale contour plots (1.6a, 1.6b) show the annual mean objective is likely to be exceeded within 20-30 metres of the edge of the M1. This is the only predicted area of exceedance within the Borough. Using the Council’s GIS (geographical information system), MapInfo, a plot has been produced mapping a 30-metre zone either side of the edge of the M1 (Figure 11.1). There are no residential properties within this zone.

Table 8.1 compares the measured and predicted nitrogen dioxide concentrations for the base year (1999) to enable the accuracy of the results to be illustrated. The accuracy of the future year modelling results are relative to the accuracy of the base year results. This means that the same degree of confidence can be placed in the future year concentrations when comparing them with the air quality objectives. The percentage difference column shows that the annual average predicted and measured concentrations are within +/- 24%.

The model overestimates predicted NO\textsubscript{2} concentrations for 2005 by 7% compared with measured readings at the Wolverton Road site and by 17% at the Miles Close location. Both locations are close to the M1. Consequently, a reasonable degree of confidence can be placed on the predicted values.
Table 8.1: Nitrogen Dioxide Concentration Validation Results for 1999 (µgm⁻³)

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Site Type</th>
<th>Measured Average</th>
<th>Predicted Average</th>
<th>Percentage Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Place, Olney Roadside</td>
<td>Roadside</td>
<td>29.0</td>
<td>25.0</td>
<td>-14</td>
</tr>
<tr>
<td>20, High Street, Olney Kerbside</td>
<td>Kerbside</td>
<td>38.0</td>
<td>29.0</td>
<td>-24</td>
</tr>
<tr>
<td>3 Miles Close, Blakelands Urban Background</td>
<td></td>
<td>29.8</td>
<td>34.9</td>
<td>17</td>
</tr>
<tr>
<td>Wolverton Road Newport Pagnell, nr. M1 bridge</td>
<td>Roadside</td>
<td>37.0</td>
<td>39.6</td>
<td>7</td>
</tr>
</tbody>
</table>

(Percentage Difference = Predicted average – Measured average X 100)

8.2 Particulate Matter (PM₁₀)

This assessment considers two air quality objectives for PM₁₀: the fixed 24-hour mean of 50 µg/m³ not to be exceeded more than 35 times a year (the 90th percentile), and the annual mean of 40 µg/m³, to be achieved by the end of 2004. Both these objectives are equivalent to the EU Stage 1 Limit Values. The 24-hour objective is the more stringent or harder to achieve objective.

Figures 2.1.a and 2.1.b (see contour maps) show the predicted concentrations in the base case (1999) for both the annual average and 90th percentile standards, respectively. The highest concentrations follow the major roads and Figure 2.1.b (1999) shows that the 90th percentile objective has the potential to be exceeded close to the M1.

Figures 2.2.a and 2.2.b (see contour maps) show the predicted concentrations in the year 2004, for both the annual average and the 90th percentile objectives, respectively. Emphasis has been placed on non-occupational, near ground level outdoor locations where the public might be exposed for a substantial part of the day. These two figures show that both the objectives are unlikely to be exceeded at locations where the public are likely to be exposed.

Table 8.2 compares the measured and predicted PM₁₀ concentrations for the base year to enable the accuracy of the results to be illustrated. The accuracy of the future year modelling results are relative to the accuracy of the base year results. This means that the same degree of confidence can be placed in the future year concentrations when comparing them with the air quality objectives. The percentage difference column shows at the annual average predicted and measured concentrations are within +/- 14% of each other in the majority of areas. Bearing this in mind, concentrations of PM₁₀ are unlikely to exceed the annual average objective or the 90th percentile objective at locations where the public will be exposed.
Table 8.2: PM$_{10}$ Concentration Validation Results (µg/m$^3$, gravimetric)

<table>
<thead>
<tr>
<th>Site Location</th>
<th>Site Type</th>
<th>Measured average</th>
<th>Predicted average</th>
<th>Percentage difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market Place, Olney</td>
<td>Roadside</td>
<td>18.9</td>
<td>21.6</td>
<td>14</td>
</tr>
<tr>
<td>Outside 20 High St, Olney</td>
<td>Kerbside</td>
<td>23.8</td>
<td>21.4</td>
<td>-10</td>
</tr>
<tr>
<td>Civic Offices</td>
<td>Urban Background</td>
<td>22.4</td>
<td>21.3</td>
<td>-5</td>
</tr>
<tr>
<td>3, Miles Close, Blakelands</td>
<td>Urban Background</td>
<td>20.8</td>
<td>22.3</td>
<td>7.2</td>
</tr>
<tr>
<td>Wolverton Rd, Newport Pagnell (near M1 Bridge)</td>
<td>Roadside</td>
<td>24.3</td>
<td>21.7</td>
<td>-10.6</td>
</tr>
</tbody>
</table>

(Percentage Difference = \( \frac{\text{Predicted average} - \text{Measured average}}{\text{Measured average}} \times 100 \))
8.3 Carbon Monoxide

This assessment considers the running 8-hour mean objective of 11.6 mg/m$^3$ to be achieved by the end of 2003. Figures 3.1.a and 3.2.a show the predicted maximum running 8-hour mean concentrations for the years 1999 and 2003, respectively. The highest concentrations of carbon monoxide are found at Junction 14 of the M1. Predicted carbon monoxide concentrations in 1999 range from 2.5 mg/m$^3$ to 4.55 mg/m$^3$ and elevated levels are due to busy congested traffic. These concentrations are well below the 11.6 mg/m$^3$ objective.

As real-time monitoring data for carbon monoxide was not available when modelling was undertaken, the predicted concentrations couldn’t be validated against measured values obtained from locations in Milton Keynes. However, there have been no exceedances of the carbon monoxide standard at any of the nearby DETR AUN stations since 1996. These sites include Oxford City, Leicester Centre and Birmingham East.

Carbon monoxide analysers were installed in the air quality stations in July and August 2000. Early results confirm that levels are well within the objective value at all three monitoring locations.
9 CONCLUSIONS

Current levels of nitrogen dioxide exceed the annual air quality objective in the vicinity of the M1 motorway and smaller sections of the A5 dual carriageway. An exceedance of the annual average nitrogen dioxide objective is predicted in 2005 within about 20-30 m of the M1 motorway. This area does not include any residential properties. The objective is therefore met at all relevant locations where members of the public are likely to be exposed. Milton Keynes Council is confident in the validity of the modelling predictions and does not propose to designate this area as an Air Quality Management Area (AQMA).

Predicted levels of carbon monoxide compare well with DETR AUN site measured concentrations and are expected to be well below the air quality objective in the year 2003. Pollution trends indicate significant reductions in CO emissions are expected by this date.

Predicted levels of PM$_{10}$ compare well with measured concentrations and are expected to be below the air quality objectives in the year 2004.

The measured and modelled studies in Olney have indicated the presence of a small “street canyon” effect in High Street South, that has produced some results of up to 20% higher than the rest of the town. However, modelling predictions indicate that all prescribed pollutant objectives are currently being achieved and should still do so by the relevant objective date.

The objectives for benzene, 1,3-butadiene, lead and sulphur dioxide are currently being met and downward pollution trends indicate further improvements in the future concentrations of these pollutants will be made.
10 RECOMMENDATIONS / FUTURE PROPOSALS

CES have recommended that the monitoring programme at the time of the modelling exercise is continued and expanded to gather more nitrogen dioxide measurements close to the M1 motorway.

A new mobile air quality monitoring station has been re-located to the previously used site on Wolverton Road, Newport Pagnell. The original mobile air quality monitoring station has been sited in Burgess Gardens, Newport Pagnell, a residential area 85 metres from the edge of the M1, away from local road traffic influences, since 14th November 2000. Milton Keynes Council is also considering installing chemiluminescent nitrogen dioxide analysers in close proximity to the motorway. Additional nitrogen dioxide diffusion tubes will also be located in residential areas close to the M1.

Carbon monoxide monitors have been added to the air quality stations to gather data and validate the model in congested areas of the Borough.

The additional data will be used for the next review and assessment of air quality in the Borough, which must be completed by the end of 2003. The AAQuIRE model will be run using updated information including air quality data and traffic flows and speeds (from the Saturn model) as part of the assessment process. Account will be taken of any legislative changes, new guidance or research in this process. However, the collection and analysis of air quality data is an on-going process within Milton Keynes Council and not a periodic exercise.
REFERENCES


CES (Consultants in Environmental Sciences), Milton Keynes Council Review and Assessment of Air Quality, Third Stage Report, December 2000.


DETR, National Road Traffic Forecasts (Great Britain), 1997.


National Air Quality Information Archive. Available on the Internet at the following address http://www.aeat.co.uk/netcen/airqual/

National Society for Clean Air and Environmental Protection. Air Quality Management Areas: Turning Reviews into Action.
National Society for Clean Air and Environmental Protection. Consultation for Local Air Quality Management: the how to guide.

The revised DETR local air quality management guidance notes published 2000 and used in the review and assessment procedure are as follows:

General Guidance

LAQM.G1(00) Framework for Review and Assessment of Air Quality. - setting out the general principles of reviewing and assessing air quality, the information authorities should collect and collate to complete a review and assessment, and the role of reviewing and assessing in local air quality management.

LAQM.G2(00) Developing Local Air Quality Action Plans and Strategies: the Main Considerations - providing general advice on the principal considerations which should underpin the development of a local air quality strategy and, where necessary, an action plan.

LAQM.G3(00) Air Quality and Transport - assisting local authorities to extend and refine their traffic management plans so that they contribute to action plans to deal with poor local air quality, and to improve air quality more generally.

LAQM.G4(00) Air Quality and Land Use Planning. - advising on the links between the land use planning system and policies to improve air quality; advising on the processes local authorities and others should adopt to ensure the land use planning system makes an appropriate contribution to achieving air quality objectives; and advising on processes to ensure that air quality considerations are properly considered along with other material land use considerations in the planning process.

Technical Guidance

LAQM.TG1(00) Monitoring for Air Quality Reviews and Assessments. - advising on appropriate monitoring techniques, including protocols and advice on site selection and establishment of automatic and non-automatic equipment.

LAQM.TG2(00) Preparation and Use of Atmospheric Emission Inventories. - advising on the need for, and appropriateness of, different types of emission inventory for differing local circumstances, and outlining methodology and good practise.

LAQM.TG3(00) Selection and Use of Dispersion Models. - advising on use and selection of dispersion models including when they should be used, types available, appropriateness to specific applications, input data required, resource requirements and interpretation of results.

LAQM.TG4(00) Review and Assessment: Pollutant Specific Guidance. - advice on review and assessment for each pollutant identified in the Air Quality Regulations.
### Table 11.1 List of Contour Plots

<table>
<thead>
<tr>
<th>Figure No.</th>
<th>Contour Plot Title</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.a</td>
<td>Milton Keynes Annual Average NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>1.1.b</td>
<td>Milton Keynes 99.8$^{th}$ Percentile Hourly NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>1.2.a</td>
<td>Milton Keynes Annual Average NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>2005</td>
</tr>
<tr>
<td>1.2.b</td>
<td>Milton Keynes 99.8$^{th}$ Percentile Hourly NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>2005</td>
</tr>
<tr>
<td>1.3.a</td>
<td>Central Milton Keynes Annual Average NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>1.3.b</td>
<td>Central Milton Keynes 99.8$^{th}$ Percentile Hourly NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>1.4.a</td>
<td>Central Milton Keynes Annual Average NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>2005</td>
</tr>
<tr>
<td>1.4.b</td>
<td>Central Milton Keynes 99.8$^{th}$ Percentile Hourly NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>2005</td>
</tr>
<tr>
<td>1.5.a</td>
<td>Newport Pagnell Annual Average NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>1.5.b</td>
<td>Newport Pagnell 99.8$^{th}$ Percentile Hourly NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>1.6.a</td>
<td>Newport Pagnell Annual Average NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>2005</td>
</tr>
<tr>
<td>1.6.b</td>
<td>Newport Pagnell 99.8$^{th}$ Percentile Hourly NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>2005</td>
</tr>
<tr>
<td>1.7.a</td>
<td>Olney Annual Average NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>1.7.b</td>
<td>Olney 99.8$^{th}$ Percentile Hourly NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>1.8.a</td>
<td>Olney Annual Average NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>2005</td>
</tr>
<tr>
<td>1.8.b</td>
<td>Olney 99.8$^{th}$ Percentile Hourly NO$_2$ Concentrations ($\mu$g/m$^3$)</td>
<td>2005</td>
</tr>
<tr>
<td>2.1.a</td>
<td>Milton Keynes Annual Mean PM$_{10}$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>2.1.b</td>
<td>Milton Keynes 90$^{th}$ Percentile PM$_{10}$ Concentrations ($\mu$g/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>2.2.a</td>
<td>Milton Keynes Annual Mean PM$_{10}$ Concentrations ($\mu$g/m$^3$)</td>
<td>2004</td>
</tr>
<tr>
<td>2.2.b</td>
<td>Milton Keynes 90$^{th}$ Percentile PM$_{10}$ Concentrations ($\mu$g/m$^3$)</td>
<td>2004</td>
</tr>
<tr>
<td>3.1.a</td>
<td>Milton Keynes Maximum 8-hourly CO Concentrations (mg/m$^3$)</td>
<td>1999</td>
</tr>
<tr>
<td>3.2.a</td>
<td>Milton Keynes Maximum 8-hourly CO Concentrations (mg/m$^3$)</td>
<td>2003</td>
</tr>
</tbody>
</table>
## APPENDIX A – Air Quality Criteria

Summary of the revised objectives adopted in the 2000 National Air Quality Strategy

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Concentration</th>
<th>Objective</th>
<th>Date to be achieved by</th>
<th>Change over 1997 strategy objective</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Measured as</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>16.25 µg/m³ (5 ppb)</td>
<td>running annual mean</td>
<td>December 31, 2003</td>
<td>Tougher: i.e. same numbers, target date brought forward two years</td>
</tr>
<tr>
<td>1.3-Butadiene</td>
<td>2.25 µg/m³ (1 ppb)</td>
<td>running annual mean</td>
<td>December 31, 2003</td>
<td>Tougher: i.e. same numbers, target date brought forward two years</td>
</tr>
<tr>
<td>Carbon monoxide</td>
<td>11.6 mg/m³ (10 ppb)</td>
<td>running 8-hour mean</td>
<td>December 31, 2003</td>
<td>Tougher: i.e. same numbers, target date brought forward two years</td>
</tr>
<tr>
<td>Lead</td>
<td>0.5 µg/m³</td>
<td>annual mean</td>
<td>December 31, 2004</td>
<td>Tougher: i.e. same numbers, target date brought forward one year</td>
</tr>
<tr>
<td></td>
<td>0.25 µg/m³</td>
<td>annual mean</td>
<td>December 31, 2008</td>
<td>New objective</td>
</tr>
<tr>
<td>Nitrogen dioxide</td>
<td>200 µg/m³ (105 ppb)</td>
<td>1-hour mean not to be exceeded more than 18 times a year</td>
<td>December 31, 2005</td>
<td>Tighter limit, dropping from 286 µg/m³ (150 ppb), same target date</td>
</tr>
<tr>
<td></td>
<td>40 µg/m³ (21 ppb)</td>
<td>annual mean</td>
<td>December 31, 2005</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Particles (PM₁₀)</td>
<td>50 µg/m³</td>
<td>24-hour mean not to be exceeded more than 35 times a year</td>
<td>December 31, 2004</td>
<td>Relaxed, more exceedances allowed, target date brought forward one year</td>
</tr>
<tr>
<td></td>
<td>40 µg/m³</td>
<td>annual mean</td>
<td>December 31, 2004</td>
<td>New objective</td>
</tr>
<tr>
<td>Sulphur dioxide</td>
<td>350 µg/m³ (132 ppb)</td>
<td>1-hour mean not to be exceeded more than 24 times a year</td>
<td>December 31, 2004</td>
<td>New objective</td>
</tr>
<tr>
<td></td>
<td>125 µg/m³ (47 ppb)</td>
<td>24-hour mean not to be exceeded more than 3 times a year</td>
<td>December 31, 2004</td>
<td>New objective</td>
</tr>
<tr>
<td></td>
<td>266 µg/m³ (100 ppb)</td>
<td>15-minute mean not to be exceeded more than 35 times a year</td>
<td>December 31, 2005</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Ozone</td>
<td>100 µg/m³ (50 ppb)</td>
<td>Daily maximum of running 8-hour means, not to be exceeded more than 10 times a year</td>
<td>December 31, 2005</td>
<td>Unchanged. Not included in Air Quality Regulations for the purposes of local air quality management (LAQM)</td>
</tr>
</tbody>
</table>
APPENDIX B – Estimated Background Pollutant Concentrations

Background Concentrations of Oxides of Nitrogen, 1996, (ppb)

Maps taken from the National Air Quality Information Archive website at:
www.aeat.co.uk/netcen/airqual/
Background Concentrations of Carbon Monoxide, 1996, (ppm)

Maps taken from the National Air Quality Information Archive website at:
www.aeat.co.uk/netcen/airqual/
Background PM10 (Primary) Concentration, 1996, (µg/m³)

Maps taken from the National Air Quality Information Archive website at:
www.aeat.co.uk/netcen/airqual/

Background PM10 (Secondary) Concentration, 1996, (µg/m³)

Maps taken from the National Air Quality Information Archive website at:
www.aeat.co.uk/netcen/airqual/
APPENDIX C

DESCRIPTION OF AAQuIRE

The AAQuIRE 2000 software is a system to predict Ambient Air Quality in Regional Environments and comprises a regional air quality model and statistical package.

AAQuIRE was developed by Consultants in Environmental Sciences Ltd (CES) to meet three requirements in predictive air quality studies.

The first requirement was an immediate need for a system which produced results that could be easily interpreted by non-air quality specialists, and to allow for proper informed inclusion of air quality issues in wider forums, such as in planning processes. This was achieved by allowing results to be generated over a sufficiently large study area, and at an appropriate resolution, for the issue being considered.

The results are also presented in a relevant format, which is normally a statistic directly comparable with an air quality criterion or set of measured data being considered. For example, the PM$_{10}$ 24-hour objective of 50 µg/m$^3$ is expressed as a 90$^{th}$ percentile of hourly means. AAQuIRE can also produce results directly comparable with all ambient air quality standards, including:

- The annual average objective for nitrogen dioxide of 40 µg/m$^3$ (21 ppb).
- The 90$^{th}$ percentile of 24-hour means for PM$_{10}$ of 50 µg/m$^3$.
- The 99.9$^{th}$ percentile of 15 minute means for sulphur dioxide of 266 µg/m$^3$ (100 ppb).
- The 99.8$^{th}$ percentile of nitrogen dioxide 1-hour means of 200 µg/m$^3$ (105 ppb).

The second requirement was for a system to be based, initially, on existing and well accepted and validated dispersion models. This has two advantages. The primary one is that it avoids the need to prove a new model against the accepted models and therefore enhances acceptability. The second advantage is that when appropriate new models are developed they can be included in AAQuIRE and be compared directly with the existing models, and sets of measured data, using the most appropriate statistics.

The final primary requirement for AAQuIRE was a consideration of quality assurance and control. An important aspect of modelling is proper record keeping to ensure repeatability of results. This is achieved within AAQuIRE by a set of log files which record all aspects of a study and allow model runs to be easily repeated.

The way in which AAQuIRE operates and the models currently available within it are discussed below.

The operation of AAQuIRE can be divided into five main stages. These are:

- preparation of the input data;
generation of model input and control files;
- dispersion modelling;
- statistical treatment of dispersion modelling results; and
- presentation of results.

Both the second (file generation) and fourth (statistical interpretation) stages produce log files which record all the input file names and other data required in the processing. These form a record of a study and can be utilised directly by the appropriate stages of AAQuIRE to repeat exactly previous studies. Additionally, during the statistical interpretation stage the log data for the dispersion modelling inputs are checked to ensure that only appropriate data are combined.

The first step in operating AAQuIRE is to prepare the input data. Data are needed on:

- meteorological data expressed as occurrence frequencies for specified combinations of wind speed, direction, stability, and boundary layer height;
- road system layout and associated traffic data within and immediately surrounding the study area;
- locations and emission factors for non-traffic sources within and surrounding the study area;
- area from which traffic emissions are to be modelled;
- grid of model prediction locations (receptors);
- traffic emissions data; and
- optional background air quality diurnal profile.

The modelling is always carried out to give annual average results from which appropriate shorter period concentrations can be derived. These relationships are given in the following table:

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Relationship</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen dioxide</td>
<td>99.8th percentile of 1-hour means = 12.8365 * (annual mean NOX)0.4604</td>
</tr>
<tr>
<td>PM_{10}</td>
<td>90th percentile of 24-hour means = 1.4991 * (annual mean PM10)1.0281</td>
</tr>
</tbody>
</table>

*Pratt and Dalton, 2000*

The second stage is the generation of the model input files and control files required for the study. A concentration is calculated at each receptor, for each of the categories included in the meteorological data file for each of the pollutant sources.

The Third Stage is executing the models. A sophisticated management system allows the dispersion modelling to be carried out simultaneously on a number of machines linked by a suitable network. Also at this stage, where an input file has been split across a number of runs because of runtime constraints, the separate results files are combined into one file per category.

The fourth stage is the statistical combination of the dispersion results and the specification of the relevant averaging period. More than one profile is required because not all emission sources will
behave the same way during a day. For example traffic normally has a very clear variation during a
day which differs from that for urban heating or industrial emissions.

The final results can be processed in two ways, according to the available meteorological data. Where summary annual data, determined over a period of several years, are used then the total
day - profile of concentration is determined for each meteorological category at each receptor point. This will either be a mean value or determination of the exceedance or non-exceedance of a
standard. This value is then weighted by the occurrence frequency of the meteorological category in question and combined with the results for all other categories, each weighted for frequency of occurrence, to give the required statistic for each receptor point.

Using the hourly or 15-minute meteorological data, and diurnal profile, pollutant concentrations can be predicted for each hour/quarter hour of the year and the required statistics calculated for each receptor point in the study area.

The final stage is presentation of results. Currently the results files from the statistical interpretation are formatted to be used directly by the SURFER package produced by Golden Software Inc. Alternative formats are available to permit interfacing with other software packages. On previous projects the results have been imported into a GIS (e.g. ArcView and MapInfo).

Currently AAQuIRE uses the CALINE4 model for the dispersion of road traffic emissions and AERMOD for all other sources. Both of these models are fully validated and have been extensively used world-wide. These are relatively complex models designed for detailed studies of local areas, which are used within AAQuIRE for both local, and larger scale studies. This is considered necessary because of the frequent importance of local effects, such as individual major roads, in properly assessing ‘regional’ effects.
APPENDIX D

NITROGEN DIOXIDE AND OXIDES OF NITROGEN

Oxides of nitrogen (NOx) is a collective term used to refer to the two chemical species: nitric oxide (NO) and nitrogen dioxide (NO2). These two oxides are grouped together because most anthropogenic NO2 is derived from emissions of NO.

The majority of NO2 emitted in motor vehicles is in the form of NO which is thought to be harmless at ambient concentrations. However, it is oxidised in the atmosphere to produce NO2 which is harmful to human health. The UK has air quality standards NO2 to protect human health.

The Advisory Group on the Medical Aspects of Air Pollution Episodes (Department of Health Advisory Group on the Medical Aspects of Air Pollution Episodes. Oxides of Nitrogen - Third Report. HMSO, 1993) described NOx chemistry in the following way:

During its atmosphere lifetime, the dominant oxide of nitrogen, NO, is progressively oxidised to NO2, largely by reaction with ozone.

\[
\text{NO} + \text{O}_3 \rightarrow \text{NO}_2 + \text{O}_2
\]

The consequence of this reaction is that the amount of the total NOx emitted, which is oxidised to NO2, is often limited by the availability of ozone. Closest to sources, the fraction of the NOx present as NO2 will, in general, be low. Further from the source, in conditions of vigorous atmosphere mixing the initial NOx plume will be diluted with fresh, unreacted ozone, and the proportions of NOx, which is NO2, will be higher. The relationship between NO, NO2 and O3 is complicated by the back reaction which occurs during daylight as NO2 is photolysed by short wavelength light (>400 µm).

\[
\text{NO}_2 + \text{hv} \rightarrow \text{NO} + \text{O}^* \\
\text{O}^* + \text{O}_2 \rightarrow \text{O}_3
\]

The Quality of Urban Air Group (Department of the Environment Quality of Urban Air Group, “Urban Air Quality in the UK 1993”) add that “In polluted atmospheres other reactions take place involving hydrocarbons, aldehydes, CO and other compounds”.

The proportion of NOx, which is NO2, varies greatly with location and time. For this reason DETR Guidance suggests that it is more appropriate to first model NOx and then apply a factor to estimate the NO2 concentration. This is because a local authority has some control over the emissions of NOx but little or no control over atmospheric oxidants that oxidise NO to NO2. However, the proportion of NOx that is NO2 varies according to a number of factors including the amount of ozone available and the distance from the emission source. A variable NO2/NOx relationship was therefore used to convert annual average NOx to annual average NO2, as given in Table D.1. This relationship was taken from the DMRB (May 1999).
Table D.1: Relationship between annual mean concentrations of NO\textsubscript{x} and NO\textsubscript{2}

<table>
<thead>
<tr>
<th>NO\textsubscript{x} (ppb)</th>
<th>NO\textsubscript{2} (ppb)</th>
<th>NO\textsubscript{x} (ppb)</th>
<th>NO\textsubscript{2} (ppb)</th>
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<tr>
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<td>320</td>
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<td>340</td>
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<td>360</td>
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</tr>
<tr>
<td>250</td>
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<td>500</td>
<td>60.1</td>
</tr>
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</table>

This relationship was used for both the base and future case years as the best representation of the NO\textsubscript{2}/NO\textsubscript{x} relationship in the five local authority areas covered by this assessment. It should also be noted that as NO\textsubscript{x} concentrations are expected to decline in future years the NO\textsubscript{2} will not be limited as much by O\textsubscript{3}. This means that the future year NO\textsubscript{2}/NO\textsubscript{x} ratio is likely to increase. The short-term averaging periods were derived by applying an empirical relationship to the annual average NO\textsubscript{2} concentrations, as given in Appendix C.
Appendix B
Background Pollutant Concentrations
Appendix D

Nitrogen Dioxide and Oxides of Nitrogen
Contour Plots