

Corporation of London

Air Quality Review

Stage 3

August 1999



**CORPORATION
OF LONDON**

SUMMARY

- For the Stage 3 Review and Assessment of air quality, the Corporation of London, together with seven other Central London Authorities, commissioned Cambridge Environmental Research Consultants to undertake an air quality modelling study in central London using the computer model ADMS-Urban.
- The modelling considered nitrogen dioxide (NO₂), fine particulates (PM₁₀) and sulphur dioxide (SO₂). Of the other pollutants detailed in Air Quality Regulations 1997, carbon monoxide, lead, benzene and 1-3 butadiene are thought unlikely to result in exceedences of the prescribed objectives by 2005.
- The most recent data available on traffic counts, vehicle emission factors, industrial and other emissions were fed into the model. The emissions inventory was largely based on the London Research Centre Emissions Inventory for London. Projections of emissions for 2005 have been based on London Traffic Survey forecasts for 2005 and emission reduction factors taken from the National Atmospheric Emissions Inventory.
- Validation of the model predictions using monitoring data for 1996 and 1997 shows that the annual mean nitrogen dioxide and 99th percentile (24 hour average) PM₁₀ are well predicted, giving an error of up to 12%. It is anticipated that, providing the predicted emissions reductions are realised, the conclusions with respect to these pollutants and averages are robust. Prediction of the NO₂ hourly maximum and SO₂ 99.9th percentile (15-minute averages) demand the precise prediction of rare events and consequently are subject to greater error.
- The calculations carried out by the model show that pollution concentrations will decrease significantly across the City by 2005.
- By 2005 exceedence of the hourly maximum NO₂ objective (150ppb) is unlikely to be widespread. Exceedence of the annual mean objective (21ppb) will occur in the western half of the City and close to major roads in a 'poor' meteorological year.
- Exceedence of the current PM₁₀ objective (50µgm⁻³ as 99th percentile of maximum 24 hour means) will be evident in the year 2005 throughout the City.
- Exceedence of the SO₂ objective (100ppb as the 99.9th percentile of 15-minute mean) has the potential to occur currently in the North East corner of the City. Levels will reduce significantly by 2005 to values well below 100ppb and therefore no exceedence of the objective is anticipated.
- Given the modelled results, it is likely that the Corporation of London will declare Air Quality Management Areas for parts of the City that are at risk of failing to achieve the air quality objectives in 2005. The proposals for the Air Quality Management Areas will be made following the outcome of the review of the National Air Quality Strategy, which is anticipated to be at the end of the year.

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1. Introduction

1.1 National Air Quality Strategy and Local Air Quality Management

In 1997, the Government published a National Air Quality Strategy for the UK with the aim of creating a more strategic and integrated approach to air quality management. The Strategy attempts to embody the principles of sustainable development in formulating the Government's standards, objectives and targets for the improvement of air quality.

National and International policies are expected to deliver significant improvements in air quality throughout the Country. However the Strategy recognises that there is a significant local dimension to air quality due to factors such as traffic density and local topography. Consequently, any problem areas or 'hot spots' due to local conditions will need to be tackled at a local level.

The Environment Act 1995 laid the foundations for a nation-wide system of local air quality management. Under Part IV of the Act, local authorities are required to periodically carry out a review and assessment of air quality within their area.

The primary objective is to identify areas where air quality is unlikely to meet the objectives prescribed in the Air Quality Regulations 1997 by the year 2005. The first full review and assessment must be completed by December 1999. In addition to the review, local authorities are required to ensure that air quality considerations are integrated into decision-making processes such as land use planning and traffic management.

The National Air Quality Strategy sets *standards* and *objectives* for the following pollutants

- Benzene (C₆H₆)
- 1,3-butadiene
- Carbon Monoxide (CO)
- Lead (Pb)
- Nitrogen dioxide (NO₂)
- Particulates (PM₁₀)
- Sulphur dioxide (SO₂)
- Ozone (O₃)

Air quality *standards* have been taken from the recommendations of the Government's advisory panel - the Expert Panel on Air Quality Standards (EPAQS). They are set with regard to scientific and medical evidence of the effects of a particular pollutant on health. The levels represent minimum or no significant risk to health. They are not based on costs and benefits or issues of technical feasibility.

Air quality *objectives* represent the Government's present view of achievable air quality by the end of 2005 having regard to the actual costs, benefits and feasibility. The objectives provide the framework for determining the extent to which local policies should aim to improve air quality. Where predictions show that by the end of 2005 the objectives will not be achieved, the authority will be required to

establish Air Quality Management Areas (AQMA's). For each AQMA local authorities will prepare an action plan to achieve the air quality objectives in the designated areas.

Although ozone is one of the pollutants listed in the strategy it is not included as an air quality objective in the Air Quality Regulations 1997. This is because ozone is not emitted directly but arises from chemical reactions of oxides of nitrogen (NO_x) and Volatile Organic Compounds (VOC's) in the atmosphere under the influence of sunlight. High ozone concentrations at a particular location may have been caused by emissions of NO_x and VOC's hundreds or even thousands of kilometres away. The responsibility for achieving the ozone objective lies at national and international level. The Corporation of London does, however monitor ozone levels in the city and will continue to do so, as it is an important indicator of local air quality.

The air quality standards and objectives as detailed in the National Air Quality Strategy are given in Appendix 1.

1.2 Review and Assessment Process

The first stage for local authorities, in the national drive to improve air quality, is to carry out a comprehensive, three-stage review and assessment of air pollution. This review and assessment process involves:

- Identifying major sources of pollution - either from roads or industry.
- Collating information on emissions to air
- Monitoring air pollution.
- Identifying proposed developments that may have an impact on future air quality.
- Using computer models to make future predictions about air pollution levels.
- Identifying where air quality objectives will not be met by the year 2005.

The Corporation of London has completed Stages 1 and 2 of the review and the conclusions of this work are described in Section 2.

This report presents findings of the Stage 3 Review and Assessment of air quality, which is largely based on computer predictions. Following consultation on this report and the outcome of the review of the National Air Quality Strategy, the Corporation of London will declare Air Quality Management Areas in the locations where the 2005 objectives are unlikely to be met. Action plans detailing the proposed measures to reduce pollution concentrations and achieve compliance with the objectives will be drawn up and also be subject to public consultation.

1.3 Central London Air Quality Cluster Group

The air quality predictions or 'computer modelling' for the Stage 3 review has been carried out jointly by eight local authorities in the Central London Air Quality Cluster Group. The Cluster Group has been working together on the Stage 3 modelling assessment since May 1998. The Authorities involved are:

- Corporation of London
- City of Westminster
- London Borough of Camden
- London Borough of Hackney
- London Borough of Islington
- Royal Borough of Kensington & Chelsea
- London Borough of Lambeth
- London Borough of Southwark

2. Overview of Stage 1 and 2 Air Quality Review

The Corporation of London completed the Stage 1 and 2 Air Quality Review and Assessment in September 1998; copies of this report are available from the Department of Environmental Services, Corporation of London. The review concluded that concentrations of carbon monoxide, benzene, 1,3-butadiene and lead would comply with the objectives prescribed in the Air Quality Regulations 1997 by the year 2005. The assessment showed however that nitrogen dioxide (NO₂), sulphur dioxide (SO₂) and PM₁₀ (the fraction of particles that are very small i.e. less than 10 micrometers) may exceed the objective and would require further detailed assessment and modelling in a Stage 3 Review.

2.1 Monitoring data

Following the publication of the Stage 1 and 2 Air Quality Review the Corporation of London has continued to monitor air quality in the City. The results and techniques used for monitoring can be found in Appendix 2.

2.2 Carbon monoxide

In light of comments received about the Stage 1 and 2 Air Quality Review, further details have been included in this report to justify the decision not to carry out a Stage 3 Review and Assessment for carbon monoxide.

Carbon monoxide is monitored in a variety of heavily trafficked roadside locations across the City.

Location	Average Daily Traffic Flow 1997	Type of Monitor	Year Established
Walbrook Wharf Upper Thames Street	68900	Infra-red automatic analyser	1998
Beech Street	19200	Infra-red automatic analyser	1997
Liverpool Street	26900	Roadside pollution monitor	1996
Fleet Street	17700	Roadside pollution monitor	1996
Mansion House	14100	Roadside pollution monitor	1996
Fish Street Hill - Lower Thames Street	64440	Roadside pollution monitor	1996

Table 1

The locations of most concern regarding carbon monoxide concentrations are Beech Street, as it is a tunnel and Upper and Lower Thames Street, which has a daily traffic flow of greater than 50,000 vehicles. Appendix 3 details the roads in the City with a daily traffic flow of over 20,000 and 50,000 vehicles. The monitoring results with regard to the air quality objective for carbon monoxide are summarised in Table 2.

Location	Year	Annual Mean (ppm)	Maximum 8 hour average (ppm)	No. of hours > objective	Data Capture
Walbrook Wharf, Upper Thames Street	1998/1999 (12 months data)	2.55	7.1	0	89 %
Fish Street Hill Lower Thames Street	1996	1.98	7.5	0	86 % from April
	1997	1.46	5.82	0	87 %
	1998	1.23	4.47	0	73%
	1999	1.35	3.6	0	100 %
Beech Street	1997	2.8	12.6	6	96 %
	1998	1.8	9.65	0	96 %
	1999	1.45	6.3	0	95%

Table 2

The monitoring results do not suggest that the prescribed objective is likely to be exceeded in the City, even adjacent to the most heavily trafficked roads. Beech Street tunnel is the only site to exhibit an exceedence of the 10ppm 8 hour average objective since monitoring began.

One of the key criteria in the review and assessment process is to consider exposure. The DETR Review and Assessment Pollutant- Specific Guidance² advises that for the purpose of determining the focus of a review and assessment local authorities should have regard to the location where individuals are likely to be exposed over the average time of the prescribed objective. In the case of carbon monoxide it is 8 hours, and we should therefore be looking at non occupational, near ground level outdoor locations where individuals might be expected to be exposed e.g. in the vicinity of houses, schools and hospitals. Beech Street tunnel, which is solely used for access, would not fit into the exposure category for carbon monoxide.

The roads with greater than 50,000 vehicles per day in the City are the main West - East through route: Victoria Embankment, Upper and Lower Thames Street and Tower Hill; and New Bridge Street on the North - South through route. Of these roads, the only one with what would be considered to have slow moving traffic at any point throughout the day is a small section of New Bridge Street¹². As the buildings adjacent to this stretch of road are predominantly commercial, it is not considered that this area would fit into the exposure category for carbon monoxide.

The gradual increase in the percentage of petrol driven vehicles with catalytic converters will reduce emissions of carbon monoxide and so it is anticipated that the concentrations monitored will continue to decrease. The National Air Quality Strategy suggests that emissions will reduce by 32% in 2000, 48% by 2005 and by 54% in 2010 compared with 1995 levels. The South East Institute of Public Health (SEIPH) state that the objective for carbon monoxide will not be breached at any location in London by the year 2005, even in the vicinity of the busiest roads³.

As stated in the Stage 1 and 2 review, the Corporation of London will continue to monitor carbon monoxide levels in the city to assess the anticipated national reduction in emissions.

2.3 Particulates

A further issue not specifically addressed in the Stage 1 and 2 review was the contribution of demolition/construction site dust to total PM₁₀ in the City. It is not envisaged that any of the existing construction sites will still be in operation in 2005 and it is difficult to predict whether the current level of construction in the City will be the same in five years time. The guidance from DETR states that in order to assess air quality for the year 2005, only activities that will be in operation then should be considered.

The Airborne Particles Expert Group (APEG) report ⁴ suggests the nationally, construction site dust accounts for just 2% of the total PM₁₀ emissions. However, as there is currently a great deal of demolition and construction activity in the City, as part of the air quality review the Corporation of London will be carrying out a PM₁₀ survey around existing sites to try and establish the contribution to PM₁₀ concentrations locally.

The Corporation of London is in the process of expanding the particulate monitoring to include a Beta Attenuation Monitor at John Cass School, Aldgate.

3. Stage 3 Review and Assessment

The main aspect of the Stage 3 review and assessment is atmospheric dispersion modelling to predict current and future concentrations of NO₂, PM₁₀ and SO₂. The modelling was undertaken by Cambridge Environmental Research Consultants (CERC) for the Central London Cluster Group. The full report 'Modelling Air Quality in Central London'⁵ is available to view at the Department of Environmental Services, Corporation of London.

This report summarises the way the model was set up the results of the modelling undertaken.

3.1 Atmospheric Dispersion Modelling

Atmospheric dispersion modelling provides a means of calculating air pollution concentrations using information about the pollutant emissions rates and local meteorology and topography. The amount of pollutant released into the air can be determined from the process involved or from actual measurements. It is the concentration of the pollutant at ground level, i.e. where people are exposed to it, that is important in determining whether there is a significant risk of an air quality objective being exceeded.

3.2 ADMS Urban

For the Stage 3 review and assessment the Corporation of London, together with the Central London Cluster Group, used the ADMS-urban dispersion model provided by CERC. ADMS urban fulfilled the essential criteria for predicting air quality. These were as follows:

- Suitability for carrying out a third stage review and assessment
- Ability to predict oxides of nitrogen, PM₁₀ and sulphur dioxide to the required limits.
- Ability to produce a coarse receptor grid output (i.e. to plot all eight boroughs on a Central London wide map).
- Ability to produce a fine receptor grid output (a fine scale map of each borough).
- Ability to interface with Geographical Information System (a computer mapping package)
- Ability to meet the specified timetable and budget.
- Provision of suitable training and technical support in use of the model.

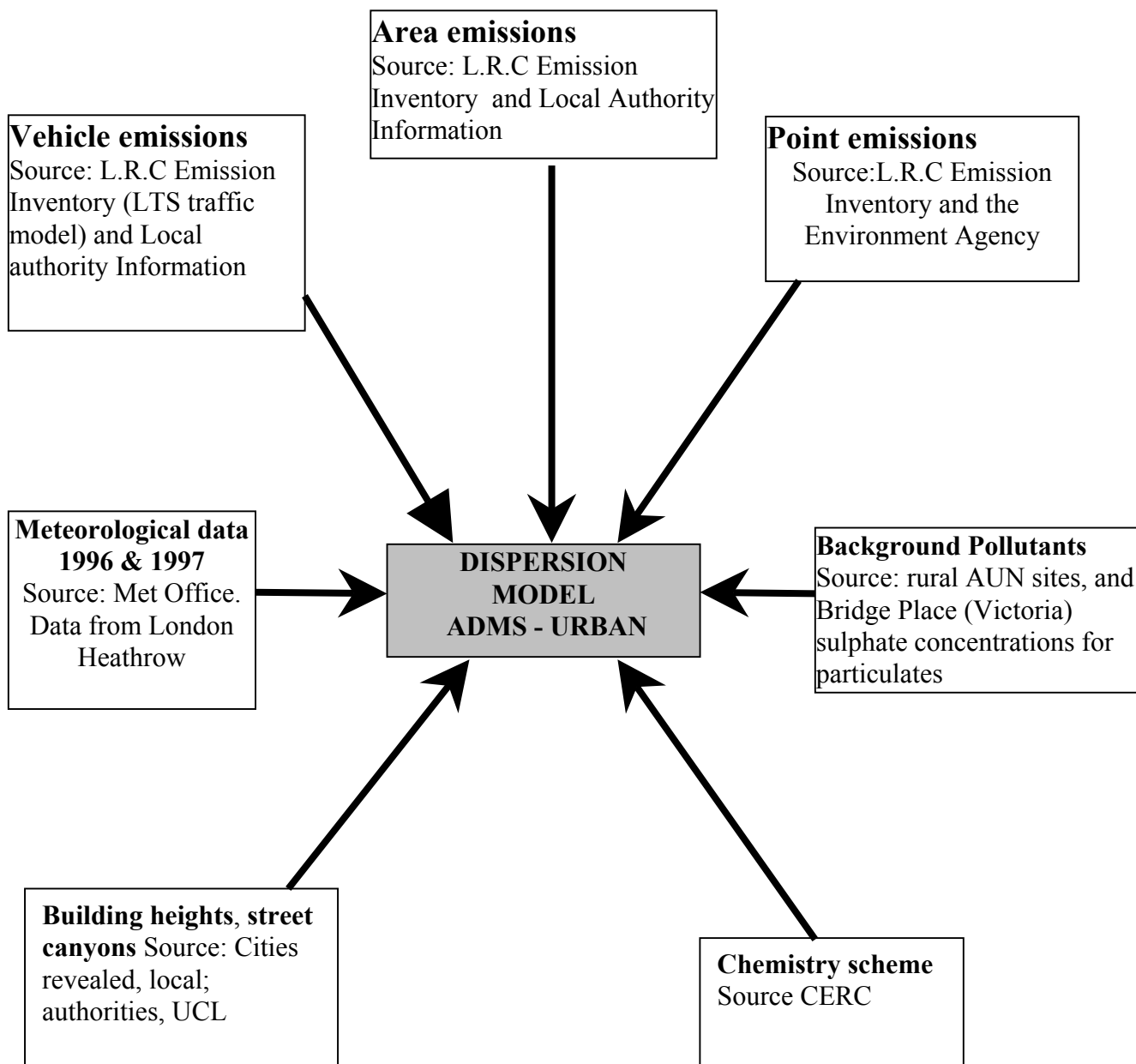
ADMS stands for Atmospheric Dispersion Modelling System. This model was originally developed for modelling emissions from industrial chimneys but has been developed to include other sources of air pollution such as roads, railways and domestic sources.

The model looks at pollution within the atmospheric boundary layer. This is the region of the atmosphere that is affected by the earth's surface and is where dispersion of pollution occurs.

3.2 Model set up

ADMS requires details of pollutant emission rates, local meteorology and topography. The modelling runs for the Stage 3 Review and Assessment used the information detailed in Figure 1.

Figure 1



3.3.1 Emissions Inventory

An emissions inventory is an organised collection of data relating to the characteristics of a process or activities that release pollutants to the atmosphere.

The emissions inventory is an integral part of air quality modelling. The inventory used in the Stage 3 Review and Assessment is based on that prepared by the London Research Centre (LRC) for Greater London⁶.

The inventory includes estimates of emissions from all significant identifiable sources within the M25. This includes industry, transport and domestic energy consumption. Emissions data are expressed for individual sources and also as total emissions arising from Ordnance Survey 1x1-kilometre grid squares. The nominal base year for the inventory is 1995, although road traffic emissions are for 1996 base year. The inventory used was for NO_x (oxides of nitrogen), SO₂, PM₁₀ and VOC's (volatile organic compounds). VOC's are included as they influence the concentration of NO₂. 1995 emission maps for Greater London for NO_x, PM₁₀, NMVOC (non-methane Volatile Organic Compounds) and SO₂ are given in Appendix 4. All of the emissions data contained within the LRC emissions database was used in the modelling study so that the impact on Central London air quality could be seen.

Road traffic emissions

Emissions from vehicle exhausts make a significant contribution to air pollution in Central London. Emissions from individual road vehicles are dependent on a number of factors such as type of vehicle, fuel use, vehicle technology (e.g. use of a catalytic converter). For each category different emission factors are used, and the emissions inventory also takes into account vehicle speed. The emissions are divided into three categories:

- a) Major road
- b) Minor road
- c) Trip ends

a) Major road

The major road network in the LRC emission inventory is taken from the London Transport Studies Model (LTS) managed and developed by MVA for the Government Office for London. All roads with an annual average daily traffic flow of greater than 20,000 vehicles and / or an average speed of less than 10km/hour were modelled. The road traffic data was supplemented by additional data from Department of the Environment Transport and the Regions (DETR) road traffic counts and data supplied by the Central London Authorities. The LTS model considers traffic on the major road network only.

b) Minor road

The minor road network is taken as a component of the 'one kilometre grid' emissions. A factor is added to the total emission rate for each kilometre grid square to account for emissions generated by traffic on minor roads. This emission rate is based on the difference between the DETR Rotating traffic census (which estimates the total vehicle kilometres travelled in London in 1995), and the kilometres accounted for by the LTS model.

c) Trip ends

Major road and minor road emissions assume normal vehicle running conditions. However when a vehicle starts it takes some time for the vehicle to reach normal operating temperature. During the 'cold start' emissions are substantially higher than when the engine is hot. This is true of petrol engines with or without a catalytic converter. Consequently an addition factor needs to be added for each 'cold start'.

In addition to cold starts a factor is added for 'hot soaks'. A hot soak is when hydrocarbons evaporate from the engine when the vehicle is in use and just after the engine is turned off.

Table 3 summarises the emissions generated by road traffic in the Greater London area for the pollutants of concern.

Greater London emissions 1995

Source	Emission rate (T/Yr.)			
	NO _x	PM ₁₀	VOC	SO ₂
Major road	96683	6616	55920	5051
Minor road	12665	933	10659	519
Non-road	42365	2291	103789	18925
Total	151713	9840	170368	24495

Source	Percentage contribution			
	NO _x	PM ₁₀	VOC	SO ₂
Major road	63.73	67.22	32.82	20.62
Minor road	8.35	9.48	6.26	2.12
Non-road	27.92	23.28	60.92	77.26

Table 3

Point sources

For the purpose of the inventory, point sources are specifically industrial operations that are licensed under Part 1 of the Environmental Protection Act 1990. The operations are divided into Part A processes regulated by the Environment Agency, these are the larger more polluting operations such as power stations; and Part B processes, regulated by local authorities. For the model runs only the South East London Combined Heat and Power Plant in Lewisham and London Underground Power Station at Chelsea were modelled as point sources for oxides of nitrogen and fine particulates. For sulphur dioxide all point sources in the LRC inventory were modelled and other significant sources outside of London. The main CERC report⁵ gives details of exactly which industrial operations were modelled in and around London.

Area Sources

Area emissions include everything else e.g. heating in offices and homes, evaporative emissions from vehicle refuelling and are averaged out over kilometre square grids.

3.3.2 2005 Emissions Predictions

In order to predict the air quality in 2005 it is necessary to predict the emissions to air in 2005. It is anticipated that the total emission of pollutants to air will be significantly less than exists at present. This is predominantly due to technological improvements and the introduction of European legislation. 2005 emission maps for Greater London for NO_x, PM₁₀, NMVOC (non-methane Volatile Organic Compounds) and SO₂ are given in Appendix 5.

The 'Auto-oil' agreements set stringent emission standards for cars and light vans to apply to all new vehicles sold from 1 January 2001 and then 1 January 2006. They are complemented by tighter fuel specifications which apply to all petrol and diesel sold after 1 January 2000 and then 2005. These measures will result in a significant reduction in emissions of PM₁₀, NO₂ and SO₂.

Additionally the European Commission (EC) has proposed emission standards to all new heavy duty diesel vehicles sold after 1 October 2001 which would represent a reduction of 30% on current emission standards.

A proposed amendment to the EC Large Combustion Plant Directive will further reduce emissions of SO₂, NO_x and PM₁₀. In England and Wales the government predict that SO₂ emissions from the electricity supply industry will fall from 1.5 million tonnes in 1998 to 365,000 tonnes in 2005 - a reduction of 75%.

For NO_x, PM₁₀ and VOC emissions in 2005 (with the exception of London Underground industrial point source in Kensington and Chelsea, which will not be in operation in 2005), only emissions from road sources have been calculated. Emissions from all other sources have been assumed to remain constant.

Road traffic

The road traffic data for 2005 was based on the LTS traffic model output. Full details of the calculations made are given in the CERC report⁵. Speed related emission factors were supplied by the National Environmental Technology Centre (NETCEN), they are based on the National Atmospheric Emissions Inventory. The vehicle emission factors were modified to take into account changes in fuel composition, which are expected to occur before 2005.

Sulphur dioxide

Emissions from Part B sources were assumed to remain constant up to the year 2005. The Environment Agency provided details on the expected changes to the Part A sources, which was limited to anticipated closures and fuel changes. Again, a complete list of changes to emission rates is given in the CERC report⁵. In view of the relatively low contribution of traffic to overall emissions of SO₂ it was assumed that these emissions would remain unchanged.

3.3.3 Meteorological Data

Given an amount of material emitted into the atmosphere (i.e. the emissions inventory), the model can be used to predict the concentration of the material at various distances from the point of release. In order to do so the meteorological conditions must be taken into account. The weather is the main factor in determining how the pollutant will be diluted and dispersed in the atmosphere.

Hourly sequential meteorological data was used from Heathrow; this was supplied by the Meteorological Office. The years 1996 and 1997 were used as the results of the model runs could be compared against existing monitoring data for validating the model (i.e. checking its accuracy). 1996 and 1997 were also quite different in meteorological terms, by comparing the model runs for each year we could see the influence that weather has on the distribution of pollutants. An example of this was demonstrated in 1996 when the weather conditions brought a larger amount of 'secondary' particulate matter from continental Europe. This resulted in a higher overall concentration of particulates in the London area than was evident in 1997.¹

The Heathrow data was adjusted to take into account the urban heating in London and the surface roughness of the City. The 1996 and 1997 data was used for both the 'base year' and 2005 model runs.

3.3.4 Background Concentration of pollutants

¹ A wide range of emission sources contribute to total PM₁₀ concentrations they are divided into:

Primary combustion particles - particles emitted directly from combustion processes e.g. road traffic, power generation.

Secondary Particles - particles formed in the atmosphere following their release in a gaseous phase e.g. sulphates and nitrates from emissions of SO₂ and NO_x

Course particles - emissions from non combustion sources e.g. sea salt, wind blown dust, construction site dust

Background concentrations of pollutants were incorporated into the model. This is the concentration of one of the key pollutants that is not emitted locally. Data from rural air quality monitoring sites around London was used in the NO₂ calculations. For the GRS chemistry scheme (see section 3.3.6) this involved NO_x, NO₂ and O₃.

To calculate the concentration of secondary PM₁₀, the daily average sulphate concentrations measured at Bridge Place monitoring site was used. A constant coarse component of 8µg/m³ was added to each hourly secondary concentration to give the total PM₁₀ background.

Table 4 shows the concentration of background pollution levels for each year. No additional background level was used for predicting sulphur dioxide concentrations.

Annual Mean of Background Concentrations of Pollutants (ppb)

Pollutant	Meteorological Year	
	1996	1997
O ₃	25.1	25.5
NO _x	12.7	14.1
NO ₂	9.7	9.6
Particulates (µg/m ³)	17.8	15.2

Table 4

Background concentration of pollutants 2005

NO_x, NO₂ and Ozone

Background NO_x concentrations were estimated from a projected 50% reduction in background NO_x between 1996 and 2005 and 45% between 1997 and 2005⁸. Background NO₂ levels were then calculated from the NO_x concentrations.

PM₁₀

2005 background PM₁₀ concentrations were based on the assumption that there will be a 30% reduction in secondary PM₁₀ between 1996 and 2010⁸. This corresponds to a 17.1% reduction from 1997 to 2005 and 19.3% from 1996 to 2005. The coarse component is not anticipated to change significantly and so remained at 8µg/m³.

3.3.5 Building Height Data

The dispersion of pollutants from road traffic is very heavily influenced by the surrounding buildings. Street canyons were identified from data supplied by MSI - Cities Revealed. For the initial model validation, street canyon heights were derived from building spot height measurements surveyed by the University College London.

The street canyons were assumed to be the same for 2005.

3.3.6 Chemistry Scheme

Nitrogen dioxide is released into the atmosphere as nitric oxide (NO) and part of this NO is converted into NO₂. The relationship between the amount of NO released and the concentration of NO₂ in the air depends on a series of complex chemical reactions. A function is therefore added to the model to calculate the concentration of NO₂ for any given situation.

Two different functions were used for comparison. The Derwent-Middleton function, which essentially uses a formula to calculate NO₂ concentrations from NO_x based on observed roadside measurements and the Generic Reaction Set (GRS) which uses seven equations involving NO, NO₂ and O₃. The results were compared against actual monitored data. The GRS scheme produced the best results and was subsequently used for the base year and 2005 model runs.

3.4 Validation

Dispersion modelling was carried out at 'receptor points', i.e. at the location of the air quality monitoring stations, and the results 'validated' or checked against the monitored data for 1996 and 1997.

Validation is important in order to assess the performance of the model. The majority of monitoring sites used in the Validation exercise across the Central London area were part of the Automatic Urban Network (AUN) which is managed and quality controlled by the DETR. City sites chosen for the validation exercise were the former Bank Reference Station (a kerbside site) and Senator House (a background site). The City sites do not form part of the AUN but are managed and operated by the Corporation of London in line with the guidance issued by AEA Technology for DETR⁷.

Nitrogen Dioxide

Thirteen sites were validated for NO₂/ NO_x. The results are summarised below:

	NO ₂ concentration (ppb)				NO _x concentration (ppb)				No. of sites used for validation
	Mean	Max	99%ile	98%ile	Mean	Max	99%ile	98%ile	
1996	3	49	23	21	-22	-35	-13	-5	7
1997	12	15	17	13	1	-18	-2	12	12

The values given represent the average percentage over/under prediction of the model when compared to the monitoring results. A negative value indicates an under prediction whilst a positive value is an over prediction.

As can be seen there is a tendency for the model to over predict the maximum NO₂, particularly for the 1996 model run. The mean is relatively well predicted.

PM₁₀

Less monitoring data was available for the validation of PM₁₀. The results are summarised below:

	PM ₁₀ Concentration µg/m ³				No. of sites used for validation
	Mean	Max	99%ile	98%ile	
1996	-6	61	-8	-8	3
1997	14	16	13	14	4

Taking the air quality objective (the 99th percentile), the 1996 calculation under predicted and the 1997 calculation over predicted. This could be due to the weather conditions in 1996 that brought more secondary particulate matter from mainland Europe. The model may have underestimated this.

Sulphur dioxide

	Annual Average	99.9%ile (15 minute average)	No. of sites used for validation
1996	-56	11	9
1997	-23	27	12

Sulphur dioxide was not as well predicted as either NO₂ or PM₁₀. The model does not take into account SO₂ blown into London and this may account for the underestimated annual average. Additionally emissions from traffic are not specifically modelled; they are averaged across a grid square.

It is inevitable that in any dispersion model there will be an element of inaccuracy as so many different factors are put into the model. The DETR guidance on air quality modelling¹⁶ advises that as a 'rule of thumb' the model should predict within $\pm 50\%$ of monitored values, otherwise the results would be considered to be poor.

4. Model results

Following the validation exercise, the following scenarios were modelled.

- a current or 'base year' scenario using a base inventory, representative of recent emissions , and 1996 / 1997 meteorological data; and
- a future scenario, corresponding to the NAQS objectives for 2005 using projected 2005 emissions and 1996 / 1997 meteorological data

The results from the scenarios are presented on contour maps depicting the concentration and distribution of the pollutants. Figures 2 to 9 depict the 'worst' prediction for each of the objectives modelled (i.e. the most unfavourable meteorological conditions). For a full set of contour maps refer to the CERC report⁵.

5. Conclusion

The modelling carried out for the Stage 3 Review and Assessment clearly shows that there will be a significant reduction in the concentrations of nitrogen dioxide, PM₁₀ and sulphur dioxide across the City of London by the year 2005. This is mainly due to the anticipated reduction in emissions, particularly from road vehicles.

The worst year meteorologically for annual mean NO₂ was 1997. This was because the wind speed was generally lower than in 1996 resulting in less dispersion of the pollutant. Should the 1997 weather pattern be repeated in 2005, the air quality objective of 21ppb will be exceeded in the western half of the City and also along major roads. The margin of exceedence is up to 9ppb. The validation exercise for annual mean NO₂ gave an over estimate of up to 12% when compared to monitored readings. Consequently the results are interpreted as being relatively well predicted.

The worst year modelled for maximum hourly NO₂ was 1996. The validation exercise showed an over-prediction of up to 49%, the results are therefore not as reliable as the results for the annual mean. Maximum concentrations of a pollutant by their nature occur in very unusual meteorological situations and are therefore very difficult to predict. The modelled results show that 1996 weather conditions would result in isolated exceedences of the 150ppb hourly objective in 2005, particularly around Bank and Mansion House tube stations.

1996 was the worst year modelled for PM₁₀; this was due to the concentration of secondary particulate matter blown over from mainland Europe. However, both meteorological years would result in widespread exceedence of the existing objective (rolling 24-hour average 50µg/m³ measured as the 99th percentile) in 2005. PM₁₀ was relatively well predicted, 1996 showed an under-prediction for the 99th percentile of 8% whilst 1997 was over-predicted by 13%.

The worst meteorological year for sulphur dioxide was 1997. However, due to the anticipated reduction in national emissions of sulphur dioxide from industrial operations, the predicted concentrations for 2005 would be less than the prescribed objective for both 1996 and 1997 weather patterns. The sulphur dioxide objective was over predicted by up to 27%, it is therefore safe to assume that there will be no exceedences of the prescribed objective.

Given the results, it is likely that the Corporation of London will declare Air Quality Management Areas in parts if not all of the City. The proposals for the Air Quality Management Areas will be made following the outcome of the review of the National Air Quality Strategy, anticipated to be at the end of the year.

6. National Air Quality Strategy Review

In order to keep abreast of developments in air quality research and changes to European Union (EU) legislation the government has committed itself to a periodic review of the National Air Quality Strategy. The first review has already been carried out and is currently undergoing consultation. The outcome of the review should be finalised by the end of this year.

The main recommendations in the first review are the proposed changes to many of the air quality standards and objectives. Table 5 summarises these proposals. As can be seen from the table, the target date for several of the pollutants is likely to be brought forward. This is partly due to anticipated improvements in air quality but also to ensure compliance with EU legislation.

The current PM₁₀ objective of 50µg/m³ set as the 99th percentile as a rolling 24-hour average is a very stringent target. The modelling carried out by CERC has shown that this objective will be exceeded across the whole of the City, and the entire central London area by 2005. One of the main reasons why PM₁₀ concentrations are not expected to reduce considerably by 2005 is due to the fact that easterly winds can often bring high levels of secondary PM₁₀ from continental Europe. Under these conditions the Government has concluded that it would be impossible for the local authorities to meet the current objective, given that the major source could not be controlled locally. The review proposes adoption of the less stringent EU stage I limit value, which is set at 50 µg/m³ as a 24-hour average, and allows 35 days on which the limit may be breached (compared to 4 for the current objective). The existing NAQS objective will be retained as an 'indicative' level.

The hourly objective proposed for NO₂ is slightly more stringent than the existing one and has been included to ensure compliance with EU legislation. However it is proposed that the annual average objective for NO₂ should retain its 'provisional' status, as further research will be necessary to test the feasibility of compliance. The new objectives that have been proposed for SO₂ will also ensure compliance with EU legislation.

The 'indicative' levels given for benzene, ozone and will not be incorporated into the regulations but are present to show the direction that the government would like to move for these pollutants. It is the intention that they will be subject to further review

The original strategy focuses on air pollution and health. In recognition of the effect that poor air quality can have on vegetation and ecosystems, the review recommends new national air quality standards for nitrogen dioxide and sulphur dioxide. However, as they are national standards they will not be included as objectives in the Air Quality Regulations at this stage. Subsequent reviews will also consider air quality standards for ozone and polycyclic aromatic hydrocarbons (PAH's) to protect vegetation and ecosystems.

In light of the review the Corporation of London will not be proposing to declare Air Quality Management Areas based on the current objectives. Once the new objectives have been confirmed a further report will be produced outlining areas of exceedence in the City with recommendations for Air Quality Management Areas.

National Air Quality Strategy				
Pollutant	Existing NAQS Standard		Objective to be achieved by 2005	Proposals for amendments to the NAQS Objectives
	Conc.	Measured as		
Benzene	5ppb	Running annual mean	5ppb	5ppb (16.2µg/m ³) by 31 Dec 2003 indicative level 1ppb (3.2µg/m ³) by 31 Dec 2005
1,3-Butadiene	1ppb	Running annual mean	1ppb	1ppb (3.2µg/m ³) by 31 Dec 2003
Carbon Monoxide	10ppm	Running 8-hour mean	10ppm	10ppm (11.65µg/m ³) by 31 Dec 2003
Lead	0.5µg/m ³	Annual mean	0.5µg/m ³	0.5µg/m ³ by 31 Dec 2004 0.25µg/m ³ by 31 Dec 2008
Nitrogen Dioxide	150ppb	1 hour mean	150ppb hourly mean	104.6ppb (200µg/m ³) hourly mean by 31 Dec 2005 (maximum of 18 exceedences)
	21ppb	Annual mean	21ppb annual mean	21ppb (40µg/m ³) retained as a provisional objective for 31 Dec 2005. New annual national objective 15.7ppb (30µg/m ³) for 31 Dec 2000 (to protect vegetation)
Ozone	50ppb	Running 8-hour mean	50ppb measured as the 97 th percentile of daily maximum 8 hour running mean (maximum 10 exceedences per year)	50ppb (100µg/m ³) retained as indicative level for 31 Dec 2005
Particles (PM₁₀)	50µg/m ³	Running 24 hour mean	50µg/m ³ measured as the 99 th percentile of daily maximum running 24 hour mean (max.4 exceedences per year)	New annual objective of 40µg/m ³ and 24 hour objective of 50µg/m ³ (max 35 exceedences) for 31 Dec 2004. 50µg/m ³ as 99 th %ile of daily maximum running 24 hour mean to be retained as an indicative level for 31 Dec 2005 New indicative annual objective of 20µg/m ³ and 24 hour level of 50µg/m ³ (maximum of 7 exceedences for 31 Dec 2009)
Sulphur Dioxide	100ppb	15 minute mean	100ppb 99.9 th percentile (a maximum of 35 exceedences per year)	100ppb (267µg/m ³) as 99 th %ile of 15 minute mean adopted as a firm objective for 31 Dec 2005. New 1 hour objective of 131ppb (350µg/m ³) maximum 24 exceedences a year 31 Dec 2004 New 24 hour objective of 48.6ppb (125µg/m ³) maximum 3 exceedences per year 31 Dec 2004 New national annual and winter objectives of 7ppb (20µg/m ³) for 31 Dec 2000 (to protect vegetation)

Table 5

Appendix 1

Air Quality Standards and Objectives as detailed in the National Air Quality Strategy

Pollutant	Standard		Objective to be achieved by 2005
	concentration	measured as	
Benzene	5ppb	running annual mean	5ppb
1,3-Butadiene	1ppb	running annual mean	1ppb
Carbon monoxide	10ppm	running 8 hour mean	10ppm
Lead	0.5µg/m ³	annual mean	0.5µ/m ³
Nitrogen dioxide	150ppb 21ppb	1 hour mean annual mean	150ppb hourly mean* 21ppb annual mean*
Ozone	50ppb	running 8 hour mean	50ppb measured as the 97th percentile*
Fine particles (PM ₁₀)	50µg/m ³	running 24 hour mean	50 µg/m ³ measured as the 99th percentile*
Sulphur dioxide	100ppb	15 minute mean	100ppb measured as the 99.9th percentile*

ppm = parts per million

ppb = parts per billion

µg/m³ = micrograms per cubic metre

* these objectives are to be regarded as provisional, they may be subject to change following the review of the National Air Quality Strategy

Appendix 2

Air Quality Monitoring Data for the City

Air quality monitoring has been taking place in the City of London since the late 1960's. A wide range of air quality monitoring is currently being undertaken. The monitoring locations and techniques have been chosen to provide a good spatial and temporal coverage of pollutants of concern.

Site location	Equipment	Site Class *	Date site established	Pollutants monitored
Guildhall - Barbican	Opsis (long path analyser)	Urban Background	1994	Nitrogen Dioxide Sulphur Dioxide Ozone
Senator House, Queen Victoria Street	Automatic real time point analyser	Urban Background	1984	Nitrogen Dioxide Sulphur Dioxide Ozone
Walbrook Wharf, Upper Thames Street	Automatic real time point analyser	Roadside	1998	Nitrogen Dioxide Sulphur Dioxide Carbon monoxide
Beech Street	Automatic real time point analyser	Roadside	1997	Nitrogen Dioxide Carbon monoxide
Beech Street	TEOM	Roadside	1998	PM10
Liverpool Street	Roadside Pollution Monitor	Kerbside	1996	Nitrogen Dioxide Carbon monoxide
Mansion House, Queen Victoria Street	Roadside Pollution Monitor	Kerbside	1996	Nitrogen Dioxide Carbon monoxide
Fish Street Hill	Roadside Pollution Monitor	Kerbside	1996	Nitrogen Dioxide Carbon monoxide
Fleet Street	Roadside Pollution Monitor	Kerbside	1996	Nitrogen Dioxide Carbon Monoxide
Guildhall	'Bubbler'	Urban Background	1978	Sulphur Dioxide Black smoke

* Site classification is based on the DETR guidance 'Monitoring for Air Quality Reviews and Assessments' ¹⁶

Diffusion tube sites in the City

Location	Nitrogen Dioxide	Benzene, Toluene and Xylene	Site classification
London Bridge	x	x	Roadside
St Andrews by the Wardrobe, Queen Victoria Street	x	x	Roadside
St Dunstons, Fleet Street	x	x	Roadside
Amen Corner	x		Roadside
St Paul's Churchyard	x	x	Urban centre
St Bartholomew's Hospital	x	x	Urban centre
Goswell Road	x	x	Roadside
Silk Street	x		Roadside
Speed House , Barbican	x		Urban background
Pleach Walk, Barbican	x	x	Urban background
Harrow Place	x	x	Roadside
Gravel Lane	x		Roadside
Finsbury Circus		x	Urban centre
Mansion House		x	Urban centre

Nitrogen Dioxide

Passive sampling (diffusion tube)

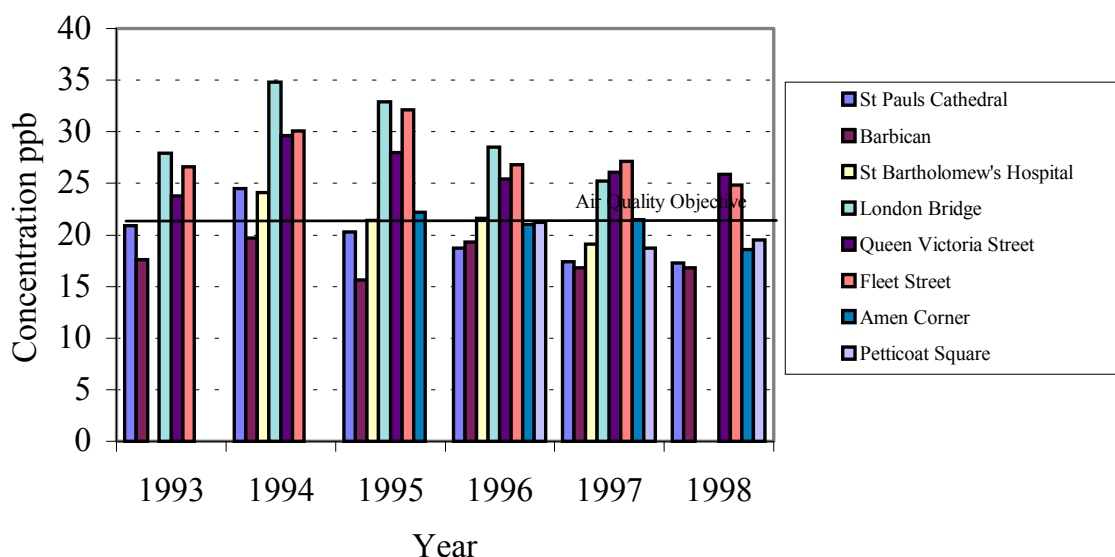
Diffusion tubes are passive devices that are used for monitoring nitrogen dioxide (NO₂) in the City. A chemical media inside the tube adsorbs the gas and concentrations are determined later in a laboratory. Nitrogen dioxide tubes are exposed for four weeks. They provide a general indication of average pollution concentrations and are useful for highlighting 'hotspots' which may warrant more detailed investigation.

The Corporation is part of a London wide diffusion tube survey that commenced in 1986. It is co-ordinated by Stanger Science and Environment who carry out quality control procedures and validate the results. The Corporation is also part of the UK Nitrogen Dioxide Survey, which is co-ordinated and quality controlled by AEA Technology.

A recent study undertaken by Stanger Science and Environment and NETCEN²⁰ estimates that urban background NO₂ tubes over estimate ambient NO₂ by approximately 9% at exposed sites and under estimate by 10% at sheltered sites when compared to automatic chemiluminescent analysers.

The graph below shows the annual average nitrogen dioxide concentrations monitored by diffusion tubes at selected sites in the City

Annual Average Nitrogen Dioxide Concentrations
(Diffusion Tubes)



Opsis (long path analyser)

Nitrogen dioxide is continuously monitored using an Opsis monitor.

The Opsis analyser is located on the roof of the north block of the Guildhall. It receives a beam of light projected from the roof of the Barbican Arts Centre. The pollution levels are averaged across the length of the light beam providing information for a relatively large area. The equipment calculates the 60 second average concentration for each pollutant. Fifteen readings per hour are collected for each pollutant and the data is collected and analysed on a computer, the nitrogen dioxide data is given as hourly averages.

Enviro Technology plc calibrate the Opsi once every 6 months. The Corporation of London carry out quality control on the data. The accuracy of the data depends on a range of factors including the accuracy of calibration. It is estimated to be $\pm 10\%$.

Automatic, real time point analyser

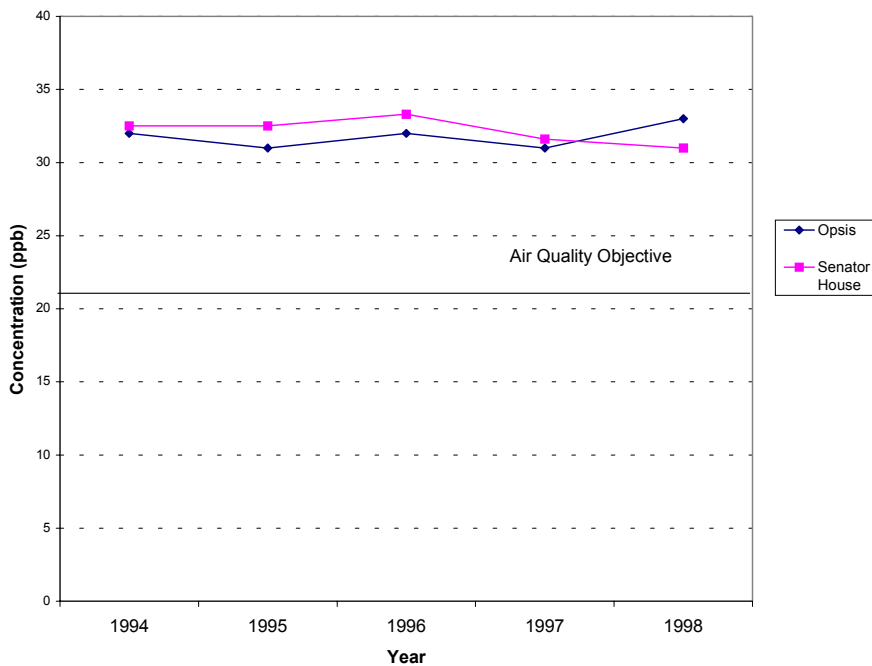
The NO₂ monitors at Beech Street, Walbrook Wharf and Senator House are chemiluminescence analysers. The determination of oxides of nitrogen is based on the chemiluminescent energy emitted when nitric oxide (NO) is reacted with ozone (O₃) to form chemiluminescent nitrogen dioxide. The analysers are compliant with the international standard for this type of equipment²¹.

An accuracy of $\pm 8\%$ has been estimated for NO₂ measurements using this method. The precision of the instruments is estimated to be ± 3.5 ppb.

The quality control procedures as detailed in the National Environmental Technology Centre (NETCEN) site operator's manual⁷ are followed for the equipment. The analysers are calibrated once every two weeks using gases traceable to national standards. All data is scaled in line with fortnightly calibration checks. The analysers also perform overnight span checks and are serviced every 6 months.

The graph below shows the annual average nitrogen dioxide concentrations at the Opsi and Senator House urban background sites 1994 to 1998

Annual Average Nitrogen Dioxide



Roadside Pollution Monitors

The city has four roadside pollution monitors provided by Siemens Environmental Systems Ltd. The monitors give a general indication of pollution levels at roadside locations. All four sites are classified as kerbside. They and are currently located at:

Mansion House: the central reservation of Queen Victoria Street outside the Magistrates Court

Fetter Lane: the south side of Fleet Street at the junction of Fetter Lane

Fish Street Hill: on the North side of Lower Thames Street by the junction with Fish Street Hill

Liverpool Street: the west side of Bishopsgate by the junction with Liverpool Street .

These instruments are not as accurate as automatic real time point analysers but provide a good indication of the trends of pollutants. They are serviced once a year by Siemens Environmental Systems Ltd.

Particulates (PM₁₀)

TEOM Particulate monitor PM₁₀

In October 1998 a roadside particulate monitor was established at the side of Beech Street. The instrument is a TEOM (Tapered Element Oscillating Microbalance). The PM₁₀ fraction is obtained via a separator and the air is passed through an oscillating balance head, which traps the particulate matter. The weight of the dust slows down the oscillation, the energy required to obtain the original frequency is proportional to the weight of particulate matter. Fifteen-minute average concentrations are collected from the analyser. The site is classified as roadside.

The unit is serviced and calibrated once per year. The precision of the instrument has been estimated at $\pm 4 \mu\text{g}/\text{m}^3$.

The initial results are shown below

Concentration of particulate matter from the TEOM October 1998 to July 1999.

Mean $\mu\text{g}/\text{m}^3$	Maximum 24 hour value $\mu\text{g}/\text{m}^3$	99th %ile $\mu\text{g}/\text{m}^3$	Hours $>50 \mu\text{g}/\text{m}^3$	Data capture
30	69	74	526	99%

BAM Particulate Monitor

The Corporation of London is in the process of installing a beta attenuation particulate monitor in the playground of John Cass School, Aldgate. The analyser consists of a glass fibre filter located between a source of beta rays and a radiation detector (ionisation chamber). A pump draws ambient air through a filter and the reduction in intensity of beta-radiation measured at the detector is proportional to the mass of the particulate matter deposited on the filter.

Sulphur Dioxide

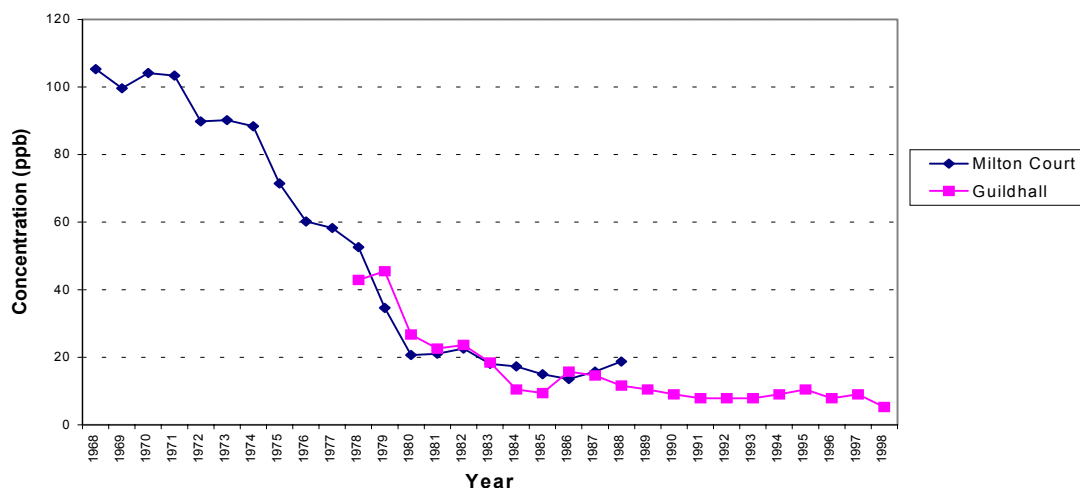
The semi-automatic sampler, monitoring sulphur dioxide and black smoke, is located on the roof of the Guildhall north block. It is classified as an Urban Background site. The Station is part of the UK Smoke and SO₂ monitoring network which dates back to the early 1960's and currently consists of over 200 sites. The survey was set up to monitor the progress of the Clean Air Acts of 1956 and 1968 which were introduced to control urban smog.

The station belongs to both the Basic Urban Network (BUN) and the EC Directive Network. Sites in the BUN have been selected to provide a representative network of monitoring locations in major

population centres and provide a long- term database of smoke and SO₂ measurements. The EC Directive network is designed to monitor compliance with the EC Directive on Sulphur Dioxide and Suspended Particulate Matter. AEA Technology co-ordinate the network and operate a quality control procedures¹⁷. This method of air quality monitoring is well established and proven and has been used in monitoring networks world-wide for many years.

The equipment, which is commonly referred to as a ‘bubbler’, comprises of a simple 8 port sampler which gives average daily concentrations of SO₂ and fine suspended particles (black smoke). A measured amount of air is drawn through a filter paper where the fine particles are deposited. The filter paper is analysed for the concentration of particles by reference to a standard light source. The filtered air is then passed in to a dilute acidified solution of hydrogen peroxide. The concentration of SO₂ is determined by chemical laboratory analysis. An accuracy of $\pm 10\%$ has been estimated for SO₂ measurements using this method

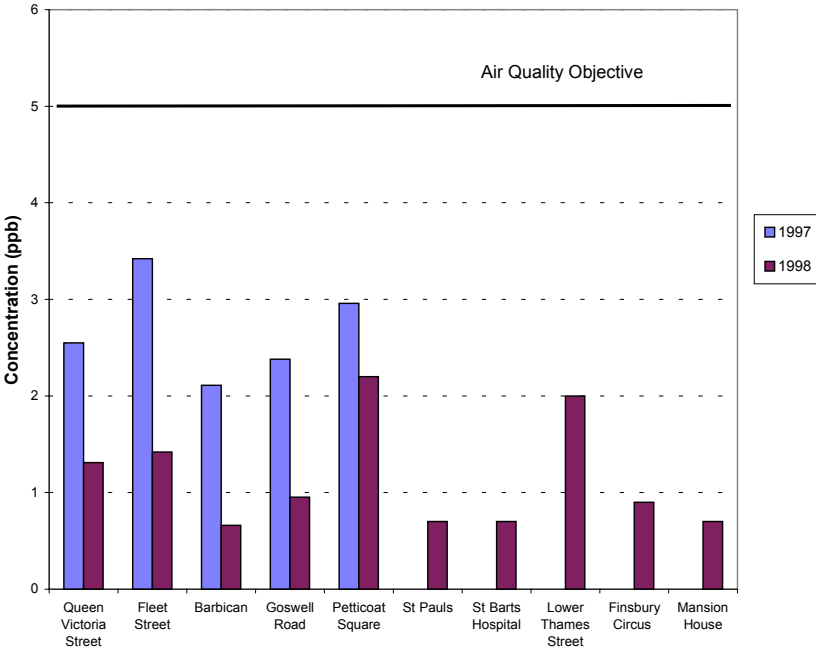
**Annual Average SO₂ Concentrations in the City
1968 to 1998**



Benzene

Benzene is monitored across the City using diffusion tubes. The tubes are exposed for two weeks in every month. Five sites were established in 1997 and a further five in 1998. The results are shown below.

Annual Average Benzene Concentrations



Appendix 3: Corporation of London Daily Traffic Flow 1997

Appendix 4 : 1995 Grid Source Emissions of NO_x, PM₁₀, SO₂ and NMVOC for Greater London

Appendix 5 : 2005 Grid Source Emissions of NO_x, PM₁₀, SO₂ and NMVOC for Greater London

References

1. Department of the Environment (1997): *The United Kingdom National Air Quality Strategy*, HMSO, London.
2. DETR (1998): *Review and Assessment Pollutant Specific Guidance*.
3. SEIPH (1997): *The Second Progress Report of the 33 Local Authorities in London. Draft Guidance on Reviewing and Assessing Air Quality for First Phase Areas*.
4. Airbourne Particles Expert Group (1999) *Source Apportionment of Airbourne Particulate Matter in the United Kingdom'*
5. Carruthers et al (1999) *Modelling Air Quality in Central London*, CERC
6. London Research Centre (1997): *London Atmospheric Emissions Inventory*.
7. AEA Technology plc *'Air Quality Monitoring: A Handbook for Local Authorities'* 1996
8. DETR (1998) *Review and Assessment: Pollutant Specific Guidance* The Stationery Office, London

9. DETR (1999) *Review of the National Air Quality Strategy*, HMSO, London
10. Corporation of London Department of Technical Services. Highways and Transportation Division (1997): *Traffic Monitoring Report 1997*.
11. Corporation of London Department of Technical Services. Highways and Transportation Division (1997): *City of London Speed Survey*.
12. DETR (1998): *Monitoring for Air Quality Reviews and Assessments*; LAQM.TG1(98), The Stationery Office, London.
13. DETR (1997): *Framework for Review and Assessment of Air Quality*; LAQM.G1(97), The Stationery Office, London
14. DETR (1998): *Preparation and Use of Atmospheric Emission Inventories*: LAQM. TG2(98) The Stationary Office, London
15. DETR (1998): *Selection and Use of Dispersion Models*: LAQM. TG3(98) The Stationary Office, London
16. AEA Technology (1997): *Instruction Manual: UK Smoke and Sulphur Dioxide Networks*.
17. NETCEN Internet Site <http://www.aeat.co.uk/netcen/aqarchive/archome.html>
18. London Research Centre Internet Site <http://www.london-research.gov.uk.etemiss.html>
19. Stanger Science and Environment and NETCEN (1999) *Validation of Nitrogen Dioxide Diffusion Tube Methodology*
20. ISO 7996:1985 *Ambient Air Determination of Mass concentration of nitrogen oxides - Chemiluminescence Method'*