Construction and its impact on Air Quality Exceedances

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Contents

1. Abstract

Air pollution affects health, bringing forward deaths, and causing long term health problems. This has led to EU and UK health-based air quality standards. London, with many parts of the UK and the EU will have problems meeting the air quality targets, and much hard work is needed, and much is in place, towards achieving the targets.

The main areas of high pollution are city centres, and the major source is road traffic, but other important sources are gas use and imported particles. Locally, construction has been found to have significant impacts on air quality. This report brings together much of the work that has been done on construction and air quality exceedances.

Construction has been found to affect the air quality PM_{10} exceedances of around 24% of the monitoring sites in the London Air Quality (monitoring)

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Network. At one site, it contributed to 29% of the air quality exceedances of PM_{10}. This is likely to become a more significant problem in the future, as the contribution from other sources reduces, that from construction will increase. At the same site as above, if a similar situation as occurred in 1999, together with similar weather occurred in 2005, then an estimated 80% of the PM_{10} exceedances at the site could due to construction activity.

2. Introduction

London is a large and rapidly growing city. Its current population of 7.4 million is predicted to increase by 700,000 over the next 15 years, in effect absorbing an additional population the size of Leeds[i]. A similar level of additional jobs is expected to be created over the same period. With this there will be a significant amount of construction activity, to enable this increase. There is an opportunity to take advantage of this tremendous growth to develop London as an exemplary sustainable world city, with both economic and environmental strengths.

It is estimated that at any one time there may be as many as 10,000 active construction sites in London, and 50,000 in the UK[ii], which is likely to increase with London's growth[iii]. Construction sites contribute to levels of pollution, and particularly particles, in London. Inner London boroughs, such as Southwark, are already observing an increase of around 50% over the last 10 years in developments coming through for planning permission, and the developments are also tending to be larger than before[iv].

Dusts from various construction processes contain a wide range of particle sizes and material types and can cause irritation to the eyes, skin and respiratory tract. With the National Air Quality Strategy in place, the declaration of air quality management areas in many parts of London and the requirement for local authorities to ensure that pollutant levels are reduced within their areas, it is becoming increasingly important that emissions from construction are also minimised.

Dust and particle generation from construction and demolition activities can be substantially reduced through carefully selected mitigation techniques and effective management. The re-use of existing building stock, instead of demolition and reconstruction, reduces emissions from both demolition and construction activities, as well as from associated transport and energy use.

As an integral part of the construction processes, vehicles and engines operating off-road for the purpose of construction will become a growing contributor of pollutant emissions and significantly affect local air quality at many locations.

Off-road vehicles and plant can contribute comparatively higher emissions because:

- they do not yet have to comply to such stringent exhaust emission regulations as their road-taxed counterparts

- regulations do not as yet require them to run on the cleaner fuels now used for road transport.

Similar policies for off-road vehicles and plant are being adopted as best practice for construction sites in cities elsewhere in Europe and within the United States, and would assist air quality in London if adopted here.

2.1. Air Quality and Health

Clean air is essential to a good quality of life. Polluted air can damage health, particularly affecting the most vulnerable in society – the very young and the old. Appendix 1 summarises the main health effects of the air pollutants covered in the Government's National Air Quality Strategy.

Individual pollutants have different potential impacts on health. These health impacts may result from short-term exposure (acute effects) or long-term exposure (chronic effects). Air quality targets are set in light of these effects. The health effects of exposure to a combination of pollutants is less well known, though may have far greater than the effects of exposure to individual pollutants[v].

Air pollution is a national and international problem. Up to 24,000 deaths of vulnerable people in Great Britain may have been brought forward, and a similar number of hospital admissions may have been associated with short-term exposure to air pollution during 1996[vi].

High levels of pollution are known to affect cardiovascular and respiratory diseases, both of which are common causes of death in London. Estimates for London suggest that 1,600 accelerated deaths and 1,500 respiratory hospital admissions per year have occurred as a result of air pollution[vii]. An additional 3,000 cardio-vascular/cerebro-vascular hospital admissions and several million minor respiratory symptoms per year have also been estimated, with less certainty, to have occurred in London as a result of air pollution.

A number of studies have looked at the health effects of short-term exposures to air pollution in London. In 1999, the Committee on the Medical Effects of Air Pollutants (COMEAP) stated that there 'is sufficient published evidence to show that daily fluctuations in exposure to current levels of air pollution in London are associated with short-term variations in ill-health'[viii].

A national study reported that a large proportion of pollution-related deaths and respiratory hospital admissions were associated with short-term exposure to particles[ix]. Long-term exposure to particles is also considered likely to be associated with deaths[x]. Particles have also been highlighted by the World Health Organisation (WHO), which describes particle air pollution as one of the three 'particularly significant' environmental factors contributing to the causes of death in Europe[xi].

Particles most likely to be inhaled into the lung are usually below about 10 µm (or 10 millionths of a metre) in diameter (PM_{10}). Evidence is emerging that the smaller fractions of particles derived from human activities, particularly those less than 1 µm in diameter, are the most harmful to health[xii]. Studies indicate that the most harmful components would be likely to be $PM_{2.5}$ and PM_1 (finer fractions of PM_{10}), though particle number, particle surface area, or even content of certain metals may in future prove of injury to health.

2.2. Background on AQ

The principal factors affecting ambient air quality are the scale of pollutant emissions, the weather, and topography (the shape of the landscape and buildings). Their interaction is complex, but in summary:

- Weather enables emissions within an area to be rapidly dispersed and diluted when conditions are favourable (e.g. windy), or prevents this dispersion when conditions are not favourable (e.g. hot and still). Weather also brings in air pollution from outside London.
- London lies within a basin and this can lead to poor dispersion or removal of pollution. Narrow, straight high-sided ‘canyon’ streets can also reduce the wind’s ability to disperse the pollution and result in build-ups and channelling of air pollution.
- The location and concentration of emissions sources influence the impact of sources on local air quality. Sources such as heating facilities tend to be more dispersed in location, whereas busy roads tend to carry a large number of emissions sources within a concentrated area. The highest pollutant concentrations are most often measured along busy roads.

Clearly it is only feasible to affect emissions, not the weather nor topography. This is therefore the mechanism used to reduce air pollution.

2.3. Air Quality Targets and Standards

The European Union (EU) has introduced legally binding targets (EU limit values) for national Governments to reduce air pollution to levels at which no or minimal effects on human health are likely to occur. In response, the UK government has introduced revised national air quality objectives for nine main air pollutants.

The levels of most of these nine pollutants are not generally of concern, and across most of Europe these targets will be met. However, many areas – particularly in cities where both emissions and people to be exposed are concentrated - 3 pollutants are of concern, particles (PM_{10}), nitrogen dioxide (NO_2) and ozone (O_3). The EU Limit Values for these three pollutants are shown in Figure 1, and are *legally binding* on the national Government, except for those labelled ‘Target’ or ‘Indicative’.

The national air quality objectives are set for similar levels, with the exception of the NO_2 objective, which is to be met in 2005, and the ozone objective which is set at 100 µg/m^3, not to be exceeded more than 10 times per year.

It is likely that there will be an additional EU Limit Value for $PM_{2.5}$ shortly[xiii]. This will concentrate more on the pollutants from man-made sources, and particularly combustion processes – motor vehicles and power stations.

Figure 1. EU air quality limit values[xiv]

Pollutant	Averaging Period	Limit values	Achievement Dates
PM_{10} Gravimetric	24 hour mean	50 µg/m^3 not to be exceeded more than 35 times a year	1 Jan 2005
	Calendar year	40 µg/m^3	1 Jan 2005
	24 hour mean	50 µg/m^3 not to be exceeded more than 7 times a year[a]	Indicative 1 Jan 2010
	Calendar year	20 µg/m^3	Indicative 1 Jan 2010
Nitrogen Dioxide	1 hour	200 µg/m^3 not to be exceeded more than 18 days per calendar year	1 Jan 2010
	Calendar year	40 µg/m^3	1 Jan 2010
Ozone	daily maximum of a running	120 µg/m^3 not to be exceeded more than 25 days per calendar year averaged over 3 years	Target value 2010

a) the UK Government has set a London objective 50 µg/m^3 of the 24 hour mean not being exceeded more than 10-14 times a year, and the annual mean as 23-25 µg/m^3
b) Gravimetric refers to the method of measuring PM_{10}
c) EU Limit Values are legally binding on national Governments.

2.4. Local Air Quality

Air quality is generally worst in urban areas – city centres, with most of the problems caused primarily by road transport. Local Air Quality Management (LAQM) is designed to help tackle this, together with national and EU measures.

In the UK, LAQM means that local authorities are legally required to assess the air quality in their area. If it is found that there is likely to be an excellence of the national air quality objectives, they are required to declare an air quality management area, and produce and air quality action plan. There are currently around 128 air quality management areas in the UK, most of them in urban areas.

2.4.1. London's Air Quality

London is likely to meet all the EU Limit Values, with the exception with those for the annual mean NO_2, the 24-hour mean, and indicative, PM_{10}, and ozone. There is much work that needs to be done at local, regional, national and EU levels to meet these Limit Values. The local authority air quality action plans, the Mayor's Air Quality Strategy, as well as the Government and EU policies all work towards that aim.

Ozone is a secondary pollutant, meaning that it is caused by levels of other pollutants (often at large distances from the high ozone levels), so can only be tackled by reducing the levels of these pollutants – mainly NO_2 and hydrocarbons.

PM_{10} and NO_2 can be reduced by reducing the levels of emissions in London, and in the case of PM_{10} also from elsewhere. PM_{10} is affected by three main groups of sources:

- Primary - those emitted from the area
- Secondary - those from outside the area, often started off as other pollutants
- Coarse – can be both local or long-range, and include fugitive construction emissions and re-suspended road dust.

The concentration of secondary particles is expected to fall as primary emissions fall throughout Europe. The coarse or 'other' particles fraction is not expected to change, thereby becoming the main PM_{10} source by 2010.

Levels of PM_{10} and NO_2 in London in 1999 are shown below in *Figure 2* and *Figure 3*[xv].

Figure 2. NO_2 levels in London in 2005, in µg/m^3

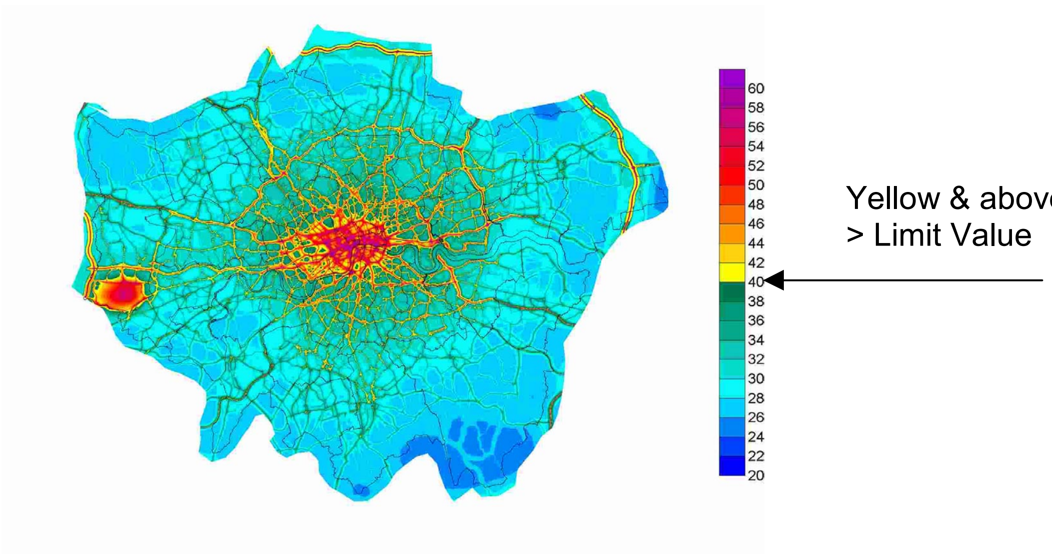
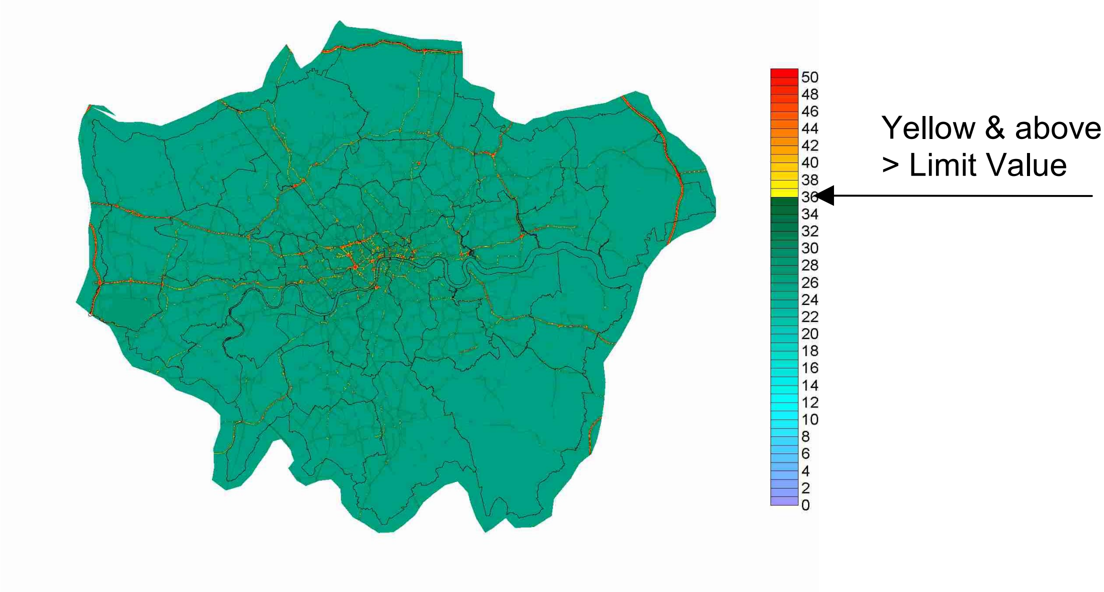


Figure 3 PM_{10} levels in London in 2004, in days over the 50 in µg/m^3 level



2.5. Where emissions come from

Road traffic is the major source affecting nitrogen dioxide levels in London, accounting for approximately 60 per cent of emissions. A further 21 per cent of emissions arise from residential and commercial gas use. Air travel from Heathrow Airport contributes both directly and indirectly to high levels of nitrogen dioxide in west London.

Seventy per cent of PM_{10} emissions occurring in London are from road traffic, but this accounts for only one third of measured concentrations of the pollutant. The remainder results from pollution from outside London transported by winds, from secondary particles formed in the atmosphere through the chemical reactions of nitrogen and sulphur-containing gases, and from dusts re-suspended by traffic on London's roads or from construction activities.

National estimates put construction at 2.5% of all PM_{10} emissions, plus a proportion of the 2.7% from non-airport off-road vehicles[xvi]. This of course will be varied geographically, with much of these emissions being emitted in urban areas, where most construction is concentrated.

Construction emissions are generally poorly covered and quantifed in emissions estimates, as they are very hard to adequately quantify and identify. There have been various individual projects on improving construction emissions estimates, by, or on behalf of, the BRE, AEA Technology, the GLA, DEFRA and others. However, these have not been sufficiently or consistently linked or funded, so have not managed to make significant improvements to construction emissions estimates.

Current estimates within the EU estimate that in Western Europe by 2010, off-road emissions – including those from construction – will be greater than those from on-road tailpipe emissions[xvii]. This makes better understanding and quantification of all off-road emissions very important the UK and the EU's future air quality.

2.6. Action to improve air quality

Due to the problems meeting the EU limit values, and the system of local air quality management in the UK, there are many measures in place to improve air quality, by different levels of Governance. These include, but are by no means limited to:

By the EU

- Euro standards
- Cleaner fuels
- Off-road vehicle standards in future….

By National Government

- Tax incentives
- Grants
- Regulations
- Legal framework….

By the London Mayor

- Mayor's Air Quality Strategy[2]
- Work towards implementing a Low Emission Zone[3]
- Cleaner buses and taxis
- Contractors requirements
- Guidance to London boroughs….

By the London Boroughs

- Air Quality Action Plans
- Low Emissions Schemes
- Roadside vehicle emissions testing
- Construction codes of practice
- Planning system
- Cleaner fleets….

3. Construction and Air Quality Exceedances

Construction work has been found to have a significant impact on air quality PM_{10} exceedances. There has been a certain amount of work assessing the impact on air quality PM_{10} exceedances of construction, and this report gathers that work together.

In London, construction and air quality exceedances was highlighted in the London Air Quality (Monitoring) Network during 1999. Cromwell Road was affected by PM_{10} from roadworks upgrading traffic signals and sensors at the road junction immediately adjacent to the site. The daily mean PM_{10} at the

[2] www.london.gov.uk/approot/mayor/environment/air_quality/index.jsp
[3] more information from www.london-lez.org, or from www.london.gov.uk

Cromwell Road site is shown in *Figure 4* compared to the Camden site, which is also situated on a busy inner London road. This shows a clear local influence during mid June[xviii].

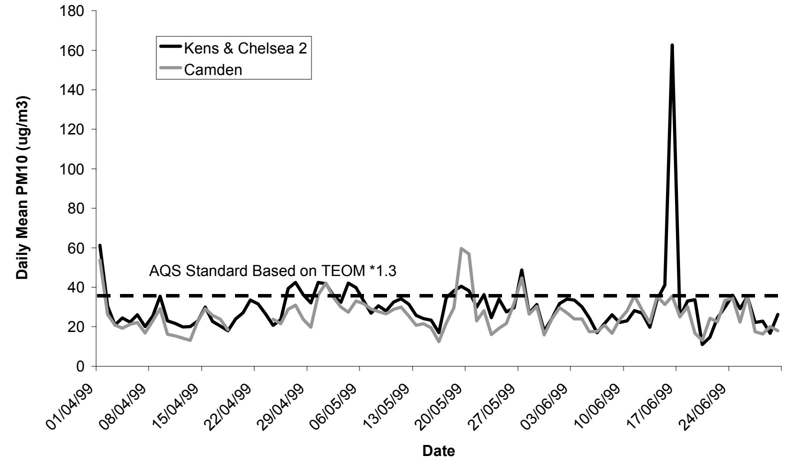


Figure 4. PM_{10} at Cromwell Road and Camden.

Marylebone Road was also significantly affected by fugitive dust, originating from building works in the nearby University of Westminster. This is shown in Figure 5 below, where PM_{10} at Marylebone Road is broadly similar to that at Camden 1 until the start of building works during mid August[xix].

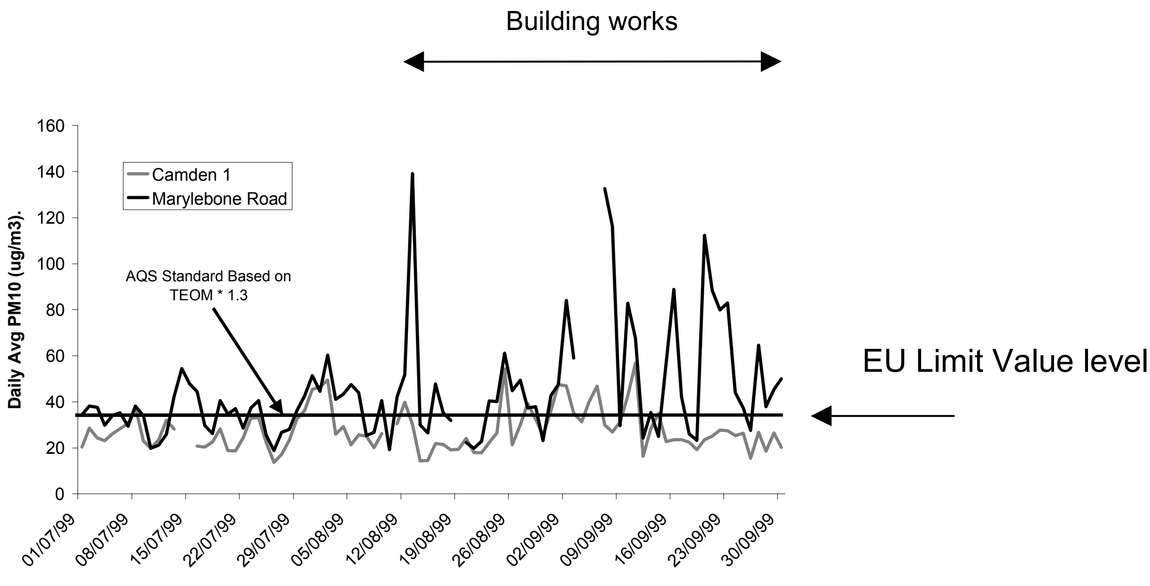


Figure 5. PM_{10} at Marylebone Road and Camden[4].

These two episodes were investigated in more detail, by Gary Fuller and David Green of ERG, Kings College[xx]. At Marylebone Road there were building works, demolition and roofing. At Cromwell Road there were streetworks, installing traffic signals and buried cables.

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[4] PM_{10} can be measured by several methods. In the UK the main two are Gravimetric – which is the method the EU Limit Value is set with, and TEOM – the method used in many of the UK monitoring sites, and where a conversion factor of 1.3 is required to convert the TEOM measurement into its Gravimetric equivalent. *Figure 5* is in TEOM measurements.

At Marylebone Road prior to the building works, PM_{10} 15 minute episodes were not normally measured over 200 µgm^{-3}. During building works, 15 minute concentrations of over 250 µgm^{-3} were observed. This was used to help identify construction events, together with a second screening method, comparing the measured data with modelled data, as the modelling does not account for the construction contribution.

The study looked first at data from 1999-2001 for 156 sites, and then concentrated on the two sites with the most construction events Cromwell Road[5] (10 days) and Marylebone Road[6] (45 days).

The screening method identified 134 daily means above 50 µgm^{-3} that might be linked to construction sources, out of 156 sites. Analysis suggests that construction sources might be associated with 5% of the 2,470 daily means above 50 µgm^{-3}, and that they occurred at almost half (37/81) of the monitoring sites, of all types (from kerbside to rural). For each of the years investigated, at least 24% of the monitoring sites experienced daily means above 50 µgm^{-3} that were associated with construction sources, and Marylebone Road measured more than 7 such days in each of the 3 years investigated.

3.1. Marylebone Road

During 14th July-30th November 1999, there were 84 days where the site measured over 50 µgm^{-3}, and modelling suggests that 24 of those incidents would not have been measured without the construction sources.

Figure 6 below shows the measurements from the site (dark line) together with the modelled results. The particularly high readings in August and September should be noted.

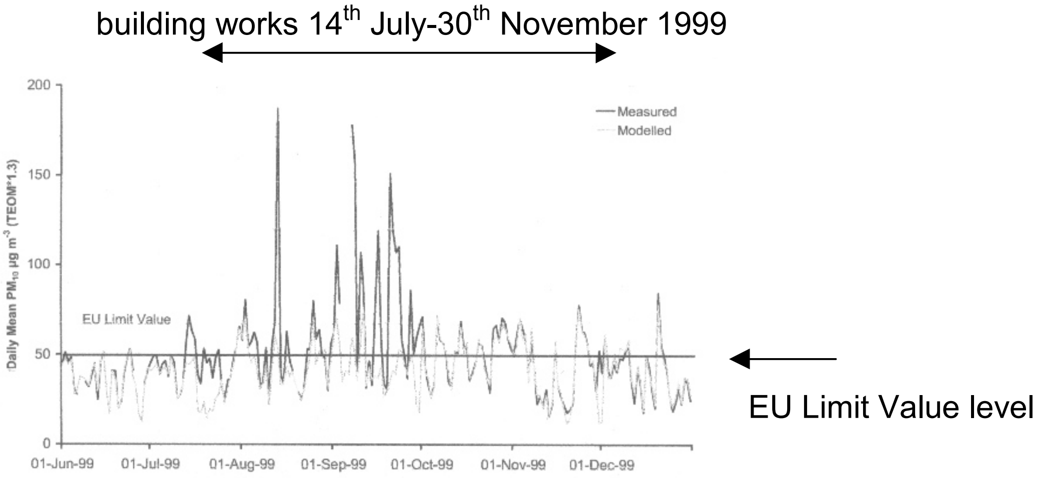

Figure 6. Daily mean modelled and measured PM_{10} at Marylebone Road

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[5] Cromwell Road (also known as Kensington and Chelsea 2): a roadside site in central London, outside the Natural History Museum. During the latter half of 1999 new traffic lights were installed at the nearby junction, requiring both the road and footpath to be dug up.

[6] Marylebone Rd: a kerbside site in central London, opposite Madame Tussauds, alongside a major arterial road with 85,000 vehicles per day. During 1999, refurbishment of an adjacent building took place, including demolition and re-roofing.

The building works at Marylebone Road frequently caused 15 minute mean PM_{10} concentrations to exceed 250 µgm^{-3} during the working day (07-17 hours), with concentrations exceeding 1000 µgm^{-3} on 4 days.

The majority of the PM_{10} is in the $PM_{2.5-10}$ fraction from the construction sources, although there is some elevation of $PM_{2.5}$ when the daily mean construction PM_{10} exceeds 50 µgm^{-3}, the EU Limit Value level. This suggests that there was significant fugitive emissions, but off-road vehicles also contributed when the EU Limit Value is breached.

3.2. Cromwell Road

At Cromwell Road, there were 51 exceedances of the 50 µgm^{-3} EU Limit Value level in 1999. *Figure 7* below shows the measurements from the site (dark line) together with the modelled results. From the measurements, the maximum level recorded was 174 µgm^{-3} on 16 June 1999, and the 50 µgm^{-3} level was exceeded on 3 days where there was no increase in ambient PM_{10} – i.e. the cause of the exceedances on 3 days could be attributed to construction sources. Using the model, 9 daily PM_{10} means above 50 µgm^{-3} would not have occurred without the construction sources.

building works 15th June -8th December 1999

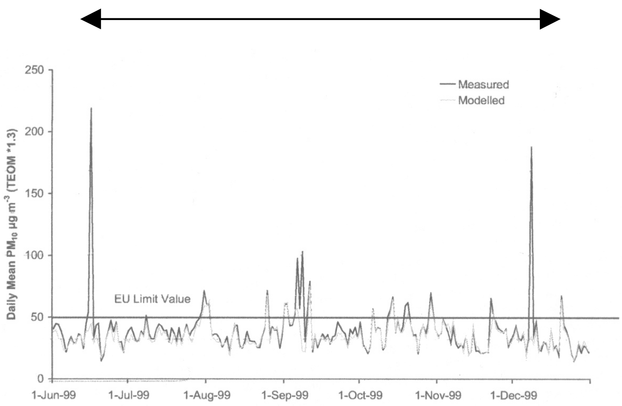

Figure 7. Daily mean modelled and measured PM_{10} at Cromwell Road

3.3. Other sites

3.3.1. Manchester Piccadilly

Another example is the high level of construction activity in Manchester Piccadilly is clearly reflected on the particulate matter graph in 2001[xxi]. This can be seen from the data for the site, shown in below.

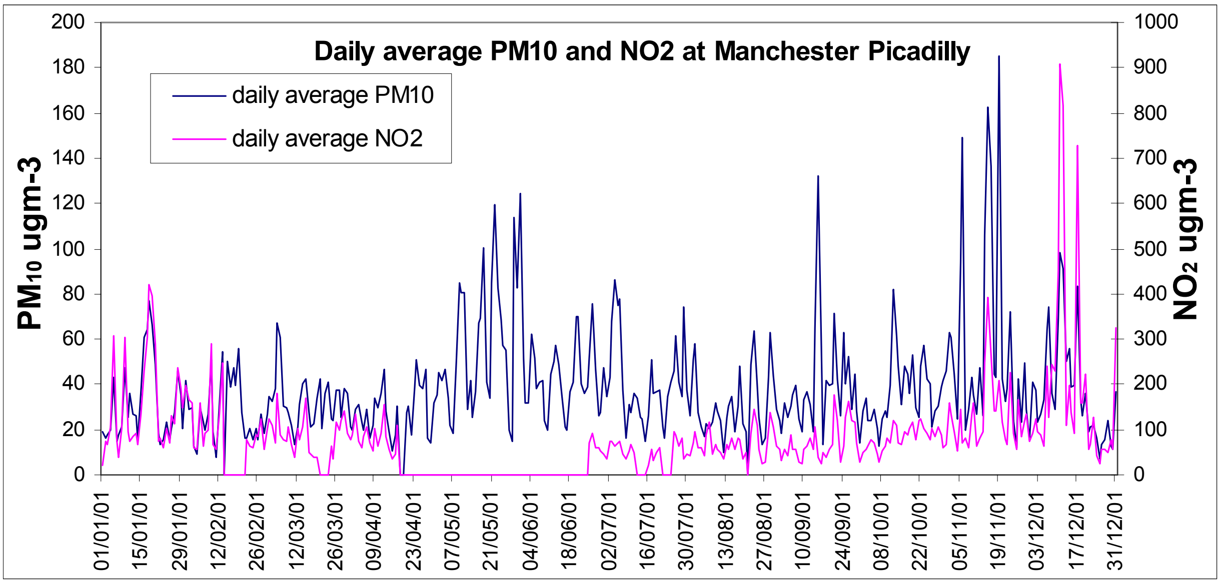

Figure ***8. PM_{10} and NO_2 at the Manchester Piccadilly Monitoring site*** [xxii]

3.3.2. Blackheath Hill

Preliminary investigation of the additional PM_{10} from works to stabilise and repair the subsidence on Blackheath Hill has been undertaken. The monitoring station was set up in March 2002 and a hole appeared in the road in April 2002. Building works went on until around Feb 2003. There were no other vehicles on that road during the construction period except construction vehicles. There were very high dust episodes in August, but the NO_2 data correlates with the dust data, which indicates plant emissions being the source of both pollutants. Preliminary investigation indicates that construction may have caused between 20 and 30 days with mean PM_{10} over the 50 μgm^{-3} level during 2002[xxiii]. This incident would warrant further investigation.

3.3.3. Cardiff monitoring site

Deacon et al[xxiv] found that data from the Cardiff AUN (the Governments Automatic Urban (monitoring) Network) site indicate that local construction and demolition activity was a significant contributor to local PM_{10} concentrations during 1994, where there were 1,319 exceedances of the 50 μgm^{-3} level in that year.

This site was investigated in depth by the Building Research Establishment[xxv] (BRE), and found that the construction processes were the most likely source of the raised PM_{10} levels. The highest particle concentrations were associated with stronger winds, the working data and the phase of the construction, especially the wall construction and internal/external finishing phases. There were short peaks in PM_{10} hourly data, and they were not correlated with the NO_2 data.

3.3.4. BRE study in Berkhamsted

A 6,500m^2 construction site in a semi-rural area was investigated by BRE[xxvi] over 18 months. The activities at the site included, demolition of industrial buildings, removal of a layer of topsoil, foundation laying and construction of a new housing development.

The results indicated that there were some increases to the background ambient concentrations of PM_{10} of the order of 2-10 µgm^{-3} at the site boundary during the construction site operating periods, and the 24-hour average PM_{10} was exceeded on 5 occasions; all of which were a combination of high background pollution episodes as well as construction emissions.

During the site preparation and earth working phases of the development were in the winter, the additional PM_{10} emissions recorded were likely to have been from exhausts of diesel engines powering the plant and vehicular trucks at the site. This is because they were in the winter, when wheel-raised emissions are likely to have been low, and the numbers of diesel powered vehicles were high.

At other times, such as during internal stripping of the buildings and decontamination activities, the buildings were maintained at reduced pressure to minimise emissions of asbestos fibres, so again, the main source of PM_{10} emissions were likely to be diesel powered vehicles that were running almost continuously.

Best practice was used to minimise emissions during the construction, and the impact on the surrounding environment was limited. However, there was still scope for significant improvement on the best practice used here, in reducing the emissions from combustion sources, especially diesel engines.

3.4. General impact on raised levels

At Marylebone Road, the construction source increased the mean PM_{10} by 16% over the 6-month period, from 42 to 50 µgm^{-3}. This pushes the Marylebone Road site even further above the annual average PM_{10} EU Limit Value level. PM_{10} levels vary for many other reasons, the most significant of these other reasons are road traffic emissions, the weather, where the wind brings other sources from. PM_{10} levels in 1999 were not that high, and had background levels been higher, as they were in 2000, or 2003[7], then the construction contribution would have pushed the concentrations and numbers of days exceeding yet further over the EU Limit Value levels.

Monitoring sites in London are generally at least 2-3 km apart. Accurately establishing the area affected by these individual incidents is not therefore possible from using the London Air Quality Network measurements alone, and would require specific studies.

In the development studies by the BRE above,[xxvii, xxviii], the mean PM_{10} concentrations were elevated between 3 and 11 µgm^{-3}, depending on what

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[7] See Appendix 1

phase of the project[8], at the site boundary during working hours. The daily average PM_{10} concentrations measured 150m from the construction site were indistinguishable from background concentrations. Further information on this study can be found in Appendix 4.

3.5. Impact in the future

Importantly for the future, with measures in place so far, sources other than construction are likely to reduce in future years. This will mean that construction will become a more significant pollution source in the future than it is at present. While this will mean that the construction, and particularly construction fugitive, sources will be able to contribute a higher concentration before causing an exceedance of 50 μgm^{-3}, the relative contribution from construction sources will increase.

The non-construction sources at Marylebone Road are predicted to reduce by 31% by 2005[xxix], which would mean that for the study period in 1999 in the above study, the number of days over 50 μgm^{-3} would reduce from 84 to 23, but only reduce those from fugitive sources from 24 to 19.

This would mean that construction sources would contribute to 80% of the total cases of PM_{10} above the 50 μgm^{-3} in 2005.

3.6. Occupational exposure

While construction may not often cause breach of the occupational exposure limits[xxx], it could still have an impact on workers health, as the following two studies highlight. The Occupational Exposure Limits for dust, set by the Health and Safety Executive are given in Appendix 4.

The Northeast States for Co-ordinated Air Use Management (NESCAUM)xxxi in the USA undertook a study into the occupational and environmental impact of non-road diesel equipment. Their study included construction (building and roadway), agricultural, and timber industries. Their report presented findings from 3 sites. They found that:

1. In all locations, diesel equipment activity substantially increased fine particulate matter (PM2.5) exposures for workers and nearby residents, in some cases by as much as 16 times
2. In-cabin exposures to PM2.5 for operators of monitored diesel equipment ranged from 2 µgm-3 to 660 µgm-3
3. Raised levels of other pollutants – acetaldehyde, benzene, and formaldehyde, iron, nickel and vanadium.

Research by the University of Washington Field Research and Consultation Group[xxxii] found that initial exposures silica and respirable dust exposures to masons during work on a campus library were above the Washington state 8-

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[8] PM_{10} levels were raised at site boundary by 3 μgm^{-3} during site preparation, ~11 μgm^{-3} during demolition, ~5 μgm^{-3} during piling and earth-working, ~2 μgm^{-3} during the construction of new buildings

hour permissible exposure levels. After dust control measures were put in place, exposures were significantly reduced.

4. London Construction Code

The Mayor and London boroughs are keen to develop best practice guidance to encourage emissions reduction from construction-related activities. Out of this aim, consulted upon in the Mayor's Air Quality Strategy, came the draft London Code of Practice, now out for consultation.

Policy 22 in the Mayor's Air Quality Strategy states:

"The Mayor will seek to develop specific best practice guidance to reduce emissions from construction and demolition sites in London."

Proposal 47 in the Mayor's Air Quality Strategy states:

"The Mayor will build on the work of other organisations to develop construction best practice guidance to encourage the reduction in levels of dust, together with other environmental impacts, from construction-related activities."

It is not the Mayor's intention to drive construction away from London but to reduce its impact on residents and make it less polluting in general. Towards that end the Mayor urge the adoption of the code, to ensure developers and contractors are aware of the requirements, to reduce emissions in particular.

The code developed, and consulted on, builds on the BRE guidance, as well as the experience and recent best-practice in London, to establish controls that are both stringent and most achievable, relevant and protect the public interest for today and the future.

5. Other Construction Codes

There are already a number of different construction initiatives. At least six London boroughs have developed their own Codes of Construction Practice (CoCPs) or Considerate Contractor Schemes that seek to control pollution and noise emissions from construction sites. The benefits to London and the construction industry of having one code are significant.

Other examples of where construction codes have been agreed for specific projects include:

- Heathrow
- Greenwich peninsula
- Kings Cross
- TfL.

It is fairly likely that similar codes will be used for any Olympics construction. Having all these codes along the same lines would help boroughs, developers and contractors in knowing what to expect.

6. Further work

There are several ways this work could be taken forward:

- Investigate whether other studies have already been undertaken on construction and air quality exceedances or exposure. This would include work undertaken by others such as the BRE, and QUARG (DEFRA's Quality of Urban Air Review Group) that are not included in this report.
- Apply the same techniques as the Marylebone and Cromwell road sites to the years 2002 to 2004, and prior to 1999. There are some further probably construction-related episodes during this period.
- If there is sufficient data, investigate the $PM_{2.5}$ and PM_{10} relationships around construction sites.
- Some work has been done to start to provide better estimates of construction emissions for emissions inventories. However, this needs to be more consistently supported, in order to develop better emissions estimation methods and factors to be used in national and local inventories. Now would be a timely juncture for some work to provide updated construction emissions, as the road transport emissions factors are undergoing a process of review and improvement, and there is recent emissions factor test data for PM_{10} and $PM_{2.5}$ in the US to update the ~20 year old USEPA emissions factors[xxxiii]. This is in addition to the fact that off-road emissions are estimated to be a more significant contributor in the future, and therefore need to be better understood – particularly construction emissions in urban areas such as London, with high levels of pollution and construction.

7. List of Appendices

Appendix 1. A summary of the health impacts of air pollutants

Appendix 2. PM_{10} levels 1998-2004 at Cromwell Road and Marylebone Road

Appendix 3. Occupational Exposure Limits 2002 for dust[xxxiv]

Appendix 4. Further information from the BRE study[xxxv]

Appendix 1. A summary of the health impacts of air pollutants[xxxvi]

Particles or particulate matter, including PM_{10} size	Particulate matter includes a wide range of sizes and types of particles, resulting from natural sources and human activities – the exact composition will vary from place to place and from time to time. Particulate air pollution is fraction associated with a range of effects on health including on the respiratory and cardiovascular systems (e.g. asthma) and mortality (deaths brought forward). Particles can also carry adhered carcinogenic compounds into the lungs. The current air quality standard is based on the PM_{10} size fraction (particles of 10 millionths of a metre or less diameter) though evidence is emerging that the smaller particle sizes are responsible for the harmful effects of particulate matter on health and that the number of particles may be a more appropriate measure rather than the mass. The main focus of research has been on the health effects of short-term exposures to ambient levels of air pollution, though long-term exposure is also considered likely to affect mortality.
Nitrogen dioxide (NO_2)	High temperature combustion processes produce nitrogen monoxide (NO) and, to a lesser extent, nitrogen dioxide (NO_2) – together termed oxides of nitrogen (NO_X). The nitric oxide reacts with ozone to form more nitrogen dioxide. Nitrogen dioxide is considered to have both short-term and long-term effects on health. At relatively high concentrations, the gas causes inflammation of the airways. Evidence also indicates that long-term exposure may affect lung function and also that exposure enhances the response to allergens in sensitised individuals. It has been suggested that apparent effects of nitrogen dioxide on health may be due to particles or, at least, are highly dependent on background particle levels.
Carbon monoxide (CO)	This is emitted from combustion processes (including vehicles) and from the oxidation of organic compounds. The main effect of carbon monoxide exposure on human health is from the formation of carboxyhaemoglobin, which substantially reduces the capacity of the blood to carry oxygen and deliver it to the tissues, and blockage of important biochemical reactions in cells. People who have an existing disease which affects the delivery of oxygen to the heart or brain are likely to be at particular risk.
Benzene (a volatile organic compound C_6H_6)	Benzene is a minor component in petrol. Studies of worker exposure in industrial workplaces have shown that those most heavily exposed have run a small, but definite, increased risk of developing certain types of leukaemia. Animal studies have shown similar effects, and have suggested moreover that benzene exerts its effect by damaging the genetic make-up of cells – in other words it is a genotoxic carcinogen. This means that it is impossible to determine a concentration to which people might be exposed at which there is no

	risk detectable by existing methods.
1,3-butadiene(a volatile organic compound, C_4H_6)	This is emitted mainly from fuel combustion in petrol and diesel vehicles but also from specific industrial processes. Workplace and animal exposure studies show 1,3-butadiene to cause certain types of cancer and to act, through other chemicals to which it is converted in the body, on the genetic material of cells (i.e. it is a genotoxic carcinogen).
Sulphur dioxide (SO_2)	This arises mainly from burning of sulphur-containing fuels. Studies have established an association (especially in presence of smoke) of SO_2 with acute mortality (i.e. deaths brought forward), and probably with hospital admissions. Sulphur dioxide causes construction of the airways by stimulating nerves in the lining of the nose, throat and airways of the lung. The latter effect is particularly likely to occur in those suffering from asthma and chronic lung disease.
Lead (Pb)	Lead arises from metal processing and, historically, from fuel combustion and waste incineration. Exposure to high levels of lead may result in toxic biochemical effects in people which in turn cause problems in the synthesis of haemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system, and acute (short-term) or chronic (long-term) damage to the nervous system. The possible effect of lead on brain development in children, and thus their intellectual development, is the greatest cause of concern.
Ozone (O_3)	This is a secondary pollutant resulting from reaction of oxides of nitrogen (NO_X) and organic compounds with sunlight. Exposure to ozone may cause slight irritation to the eyes and nose, worsening the symptoms of asthma and lung disease. Very high levels of exposure (1,000-2,000 µg/m3) over several hours, may result in damage to the airway lining followed by inflammatory reactions. There is evidence that minor changes in the airways may occur at lower concentrations, down to about 160 µg/m3. Studies have also established a relationship of ambient ozone levels with acute mortality (i.e. deaths brought forward), and hospital admissions in Europe.
Polycyclic Aromatic Hydrocarbons(PAH), a toxic organic micropollutant	Produced by incomplete combustion of fuels. PAHs are members of large group of organic compounds widely distributed in the atmosphere – the best known PAH is benzo[a]pyrene (B[a]P). Studies of occupational exposure to PAH have shown an increased incidence of tumours of the lung, skin and possibly bladder and other tissues. Lung cancer is the most obviously linked to exposure to PAH through inhaled air. The chemical and physical properties of different PAHs vary, as do their carcinogenicity. Other toxic organic micropollutants include polychlorinated biphenyls (PCBs), dioxins and furans.

Appendix 2. PM_{10} levels 1998-2004 at Cromwell Road and Marylebone Road

General PM_{10} levels vary significantly each year. *Figure 9* shows the number of days exceeding the EU Limit Value level of 50 µgm^{-3} at both the Cromwell Road and Marylebone Road air quality monitoring sites[xxxvii].

Figure 9. Days exceeding the EU Limit Value level of 50 µgm^{-3} at Cromwell and Marylebone Road sites

Year	**Days exceeding 50 µgm^{-3}**	
	Marylebone Road	Cromwell Road
1998	83	28
1999	111	51
2000	157	30
2001	106	34
2002	111	36
2003	161	56
2004	99	29

Appendix 3. Occupational Exposure Limits 2002 for dust[xxxviii]

Given below are the occupational exposure limits for dust. There will be different limits for diesel exhaust and other particular chemicals.

Dust

The COSHH definition of a substance hazardous to health includes dust of any kind when present at a concentration in air equal to or greater than 10 $mg.m^{-3}$ 8-hour TWA of total inhalable dust or 4 $mg.m^{-3}$ 8-hour TWA of respirable dust. This means that any dust will be subject to COSHH if people are exposed above these levels. Advice on control is given in *EH44: Dust: General principles of protection, 21* and in the great majority of workplaces reasonable control measures will normally keep exposure below these levels.

However, some dusts have been assigned an often accompanied by a chemical reaction such as oxidation or thermal breakdown. OEL (a MEL or an OES) and exposure to these must comply with the appropriate limit.

Most industrial dusts contain particles of a wide range of sizes. The behaviour, deposition and fate of any particular particle after entry into the human respiratory system and the body response that it elicits depend on the nature and size of the particle. HSE distinguishes two size fractions for limit-setting purposes termed 'total inhalable' and 'respirable'.

Total inhalable dust approximates to the fraction of airborne material that enters the nose and mouth during breathing and is therefore available for deposition in the respiratory tract.

Respirable dust approximates to the fraction which penetrates to the gas exchange region of the lung. Fuller definitions and explanatory material are given in *MDHS74/3: General methods for sampling and gravimetric analysis of respirable and total inhalable dust. 11*

Where dusts contain components which have their own assigned occupational exposure limits, all the relevant limits should be complied with.

Occupational health standards:

Figure 10. Maximum Exposure Limits (MEL) – substances that may cause most serious health effects for which "no adverse effect level" can be determined

Material	**Long term MEL (8h TWA) / mg/m^3**
Hardwood dust	5
Softwood dust	5

Silica (respirable crystalline)	0.3
Man-made mineral fibre	5

Figure 11. Occupational Exposure Limits (OEL) – set at level where there is no indication of risk to health of workers

Material	***Fraction***	**Long term OEL (8h TWA) / mg/m^3**
Calcium carbonate	Inhalable Respirable	10 4
Calcium silicate	Inhalable Respirable	10 4
Coal dust	Respirable	**2**
Emery Inhalable	Inhalable Respirable	10 4
Gypsum Inhalable	Inhalable Respirable	10 4
Limestone	Inhalable Respirable	10 4
Marble	Inhalable Respirable	10 4
Mica	Inhalable Respirable	10 4
Plaster of Paris	Inhalable Respirable	10 4
Portland Cement	Inhalable Respirable	10 4
Ground granulated blast furnace slag	Inhalable Respirable	10 4
Pulverised Fuel Ash	Inhalable Respirable	10 4
Silica (amorphous)	Inhalable Respirable	6 2.4
Silica (fused)	Respirable	0.08
Silicon carbide	Inhalable Respirable	10 4

Appendix 4. Further information from the BRE study[xxxix]

Some of the best practice methods undertaken included:

Site preparation & stripping

- Small access road laid
- Asbestos removed from buildings (under negative pressure)
- All fittings removed from "clean" buildings
- Scaffolding and sheeting of perimeter
- Site office porta-cabin installed

Demolition

- Buildings "nibbled" down using 360° excavator fitted with special grab
- Water sprays used to control dust
- Demolition materials sorted and removed from site
- 310 truck movements at site during 8 week demolition period

Air Pollution

- Large numbers of particles (especially ultrafines) emitted from diesel exhausts
- Particles emitted from demolition were mostly in the PM_{10} size fraction (rather than the $PM_{2.5}$ or PM_1)
- PM_{10} levels about150 m from construction site were indistinguishable from background levels
- Potential implications for planning consents, especially for sites in air quality management areas and with nearby sensitive receptors

Some of the monitoring results:

Figure 12. Westerly wind sector (250° to 290°)

Site Activity	**Downwind – upwind PM_{10} concentration Local Met data (μgm^{-3})**	**Downwind – upwind PM_{10} concentration National Met data (μgm^{-3})**
Building stripping	+4.5	+1.3
Demolition	+2.1	+3.2
Earth-working	+2.4	N/A
Total for the entire monitoring period	+2.3	+2.3

Figure 13. Easterly wind sector (70° to 110°)

Site Activity	**Downwind – upwind PM_{10} concentration Local Met data (μgm^{-3})**	**Downwind – upwind PM_{10} concentration National Met data (μgm^{-3})**
Building stripping	-0.5	-1.5
Demolition	-1.6	-2.5
Earth-working	-3.6	N/A

Total for the entire monitoring period	-1.7	-3.1

Conclusions

- No complaints were received regarding dust and particle emissions at either the site or at the local authority
- Allowed site operations to continue uninterrupted
- Site run to best practice methods
- Operating period was through winter when ground and materials were usually moist
- If PM_{10} emissions can be controlled at a sensitive site - they can be controlled at all sites.
- Emissions must be controlled at source
- Site method statements, techniques and emission controls need to be specified and agreed with local authority from the outset.
- Costs of controls need to be incorporated into all tenders for the development

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