Air Quality in London – briefing note to GLA Environment and Health Committee

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Summary

This note provides results from air quality monitoring carried out in London during 2011 and looks at changes in nitrogen dioxide and PM_{10} concentrations since 1998. Provisional results for 2011 indicate that the annual mean National Air Quality Strategy Objective (which mirrors the EU Limit Values) for NO_2 was breached at the majority of locations close to roads and at five locations away from busy roads. The NAQS objectives for PM_{10} which are in line with the EU Limit Values although the assessment method for the EU Limit Value allows several factors to be taken into account including the influence of natural sources. Two kerbside, three roadside and one industrial monitoring site measured more than the NAQS objective of 35 days with mean PM_{10} above 50 µg m^{-3}.

Changes in pollution linked to the London Low Emissions Zone (LEZ,) health research and the provision of air quality information to the public are also described briefly.

Annual mean air pollution concentrations during 2011

Pollution concentrations are measured in London by the London Air Quality Network (LAQN), a unique partnership between King's College London and the London boroughs, along with several local authorities outside London, Defra and TfL. Air pollution is measured continuously at around 100 monitoring sites. Of this number fifteen London monitoring sites are used by Defra for the assessment of EU Limit Value compliance and are reported to the EU Commission.

At the end of each year monitoring and calibration equipment at each site is briefly subjected to a series of extensive independent tests. For the majority of local authority monitoring sites these tests are carried out by the National Physical Laboratory. Measurements from the previous year are finalised following these tests. The measurements presented below are therefore provisional for 2011.

Nitrogen dioxide (NO_2)

Provisional annual mean NO_2 concentrations for 2011 are shown in Figure 1. The annual mean National Air Quality Strategy (AQS) objective / European Union (EU) limit value of 40 µg m^{-3} is shown as a broken red line. The AQS objective was exceeded alongside almost every road where measurements took place. The greatest concentrations, over three times the AQS objective, were measured at kerbside sites in Putney and Brixton. Away from roads, in background and suburban areas, the AQS objective was exceeded at five locations. These were in inner London, in some busy outer London centres and close to Heathrow and the M4.

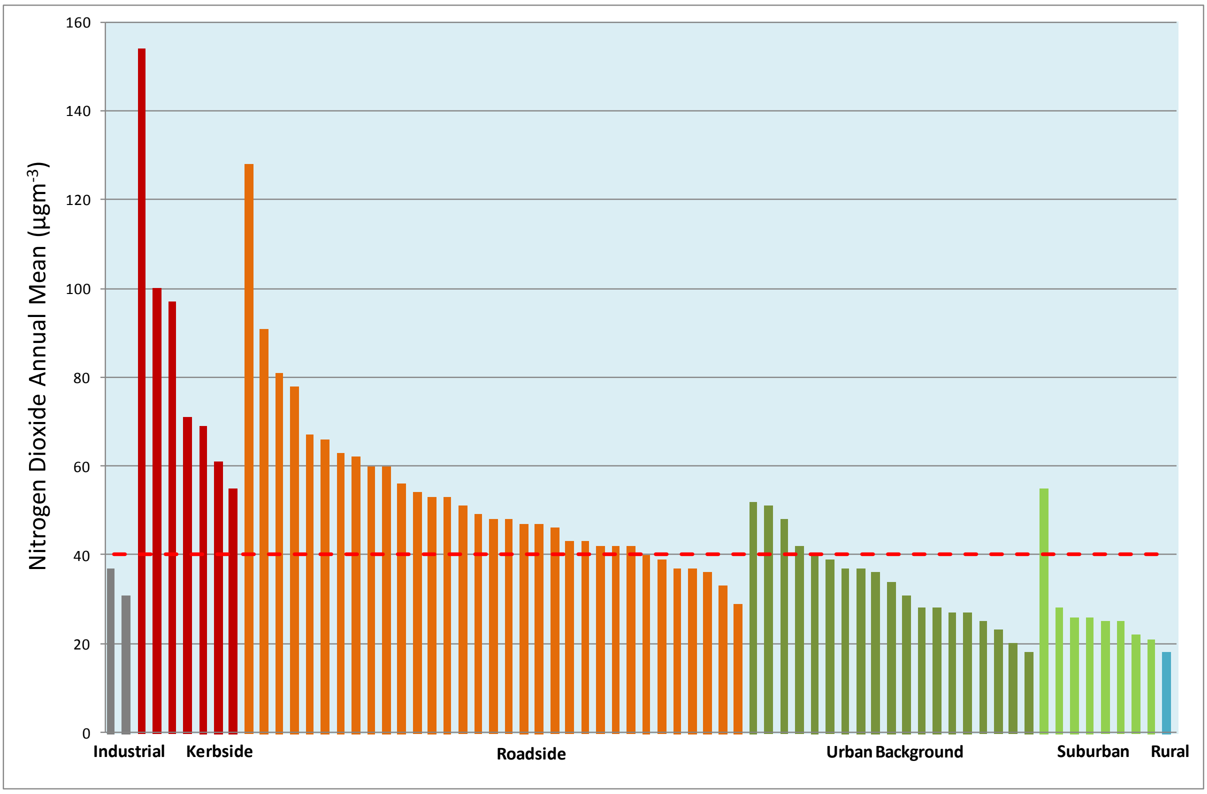

Figure 1 Provisional annual mean NO_2 at LAQN sites during 2011. The NAQS objective / EU LV is shown as broken red line and sites are grouped by type.

The NAQS and EU Directives also include limits on short-term exposure to NO_2 which is set at a maximum of 18 hours per year with mean NO_2 above 200 µg m^{-3}. Such high concentrations of NO_2 are mainly confined to locations close to busy roads. However as shown in Figure 2, nine kerb and roadside locations exceeded this threshold by a very large margin.

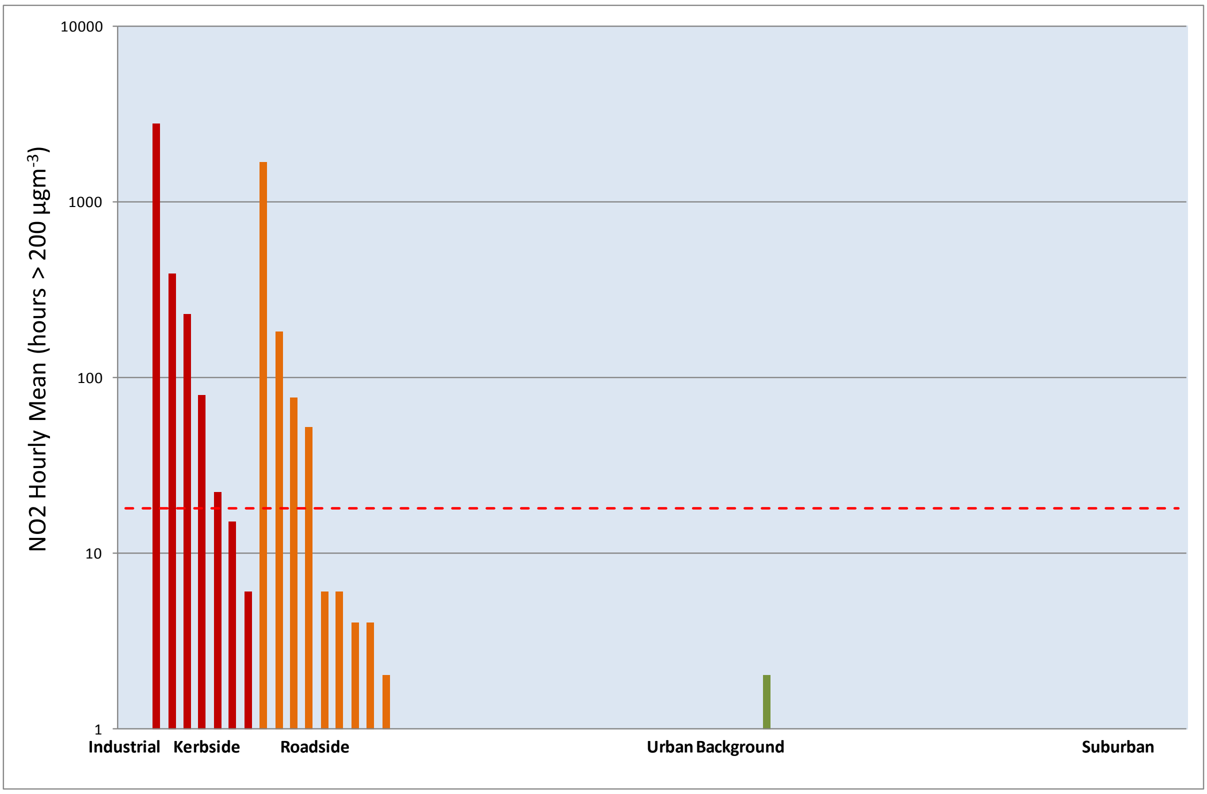

Figure 2 Provisional number of hours with NO_2 > 200 µg m^{-3} at LAQN sites during 2011. The NAQS objective / EU LV is shown as broken red line and sites are grouped by type. Note the logarithmic scale on the y axis.

NO_2 is largely a secondary pollutant with concentrations being determined by a combination of emissions of both NO and NO_2 and the capacity of the atmosphere to convert NO to NO_2. For this reason concentrations of NO_2 cannot be understood without considering the total concentrations of NO and NO_2, termed NO_X.

Monthly mean NO_X concentrations are shown in Figure 3. Mean NO_X concentrations are greater at roadside locations when compared with background. NO_X concentrations at all site types show a clear seasonal variation with the greatest concentrations being measured in winter due to poor pollutant dispersion at this time. Overall, concentrations of NO_X have fallen across all site types with concentrations falling fastest at roadside sites, though the rate of decline decreased around 2001 and concentrations but have been more stable since. The overall decrease in NO_X concentrations reflects the abatement of vehicle emissions, however, the recent stability gives rise to concern regarding control of NO_2 concentrations. The sharp reduction in NO_X concentrations at Marylebone Road during 2001 reflected the introduction of a bus lane at this time.

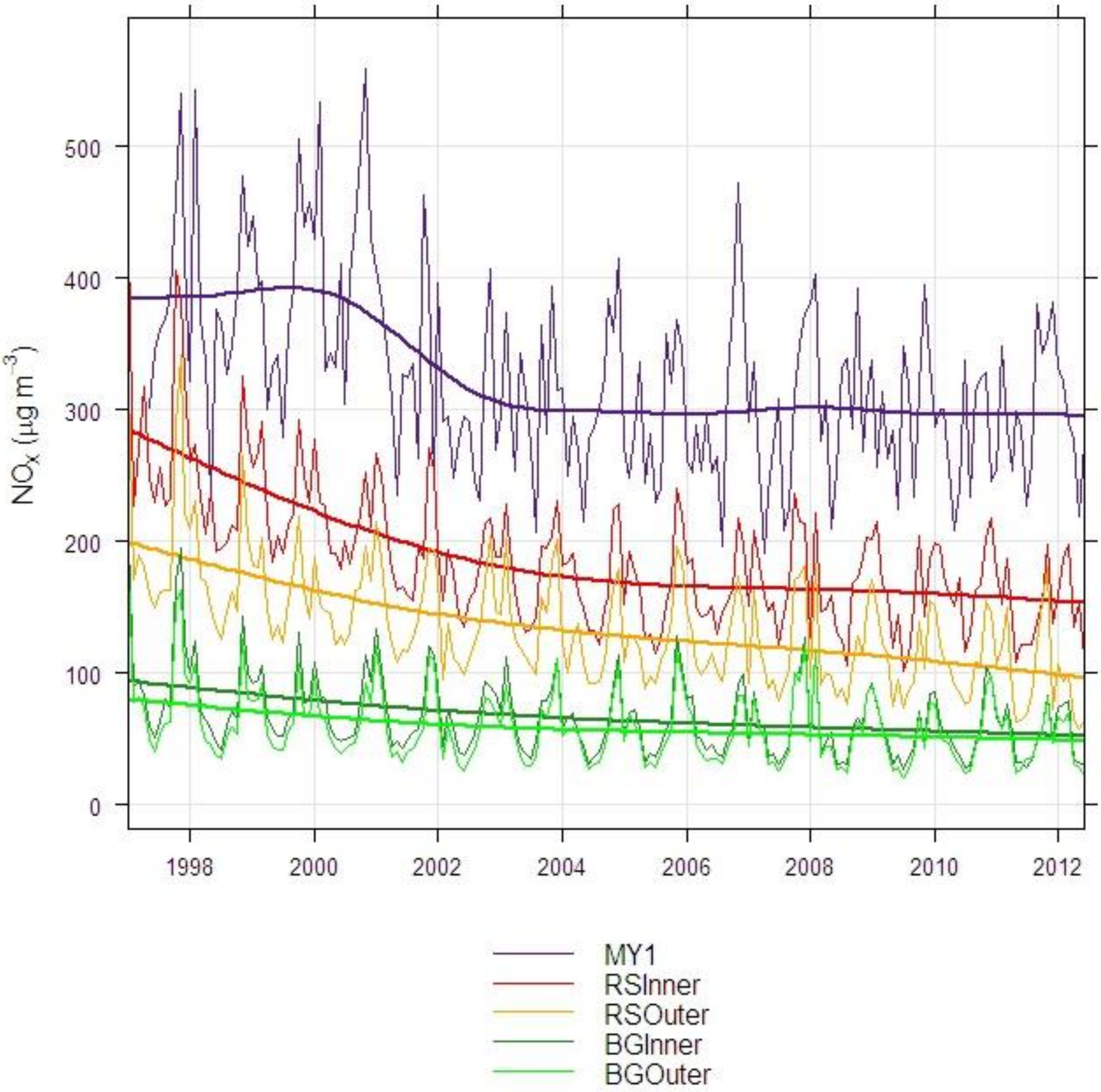

Figure 3 Monthly mean NOX concentrations at selected London monitoring sites. MY1 = Marylebone Road, RS= Roadside, BG = background, Inner and Outer refer to inner and outer London.

In line with NO_X concentrations, concentrations of NO_2 were also greatest at roadside sites with lower concentrations measured at background locations. Like NO_X, NO_2 concentrations are generally higher in wintertime due to poor dispersion.

As shown in Figure 4, NO_2 concentrations away from roads have declined since 1998 but the rate of decline has weakened in recent years. The apparent sharp declines in NO_2 concentrations during 2011 and 2012 appear to conflict with those of NO_X and should be treated with caution at this stage. Importantly, the annual mean AQS Objective and EU Limit Value of 40 µg m^{-3} has been attained at background sites in outer London only and this concentration has been consistently exceeded at background sites in inner London and at roadside sites throughout London. It is clear that the difference between NO_2 concentrations at roadside and at background sites increased since 1998. This can be attributed to an increase in the proportion of NO_2 being directly emitted in vehicle exhausts.

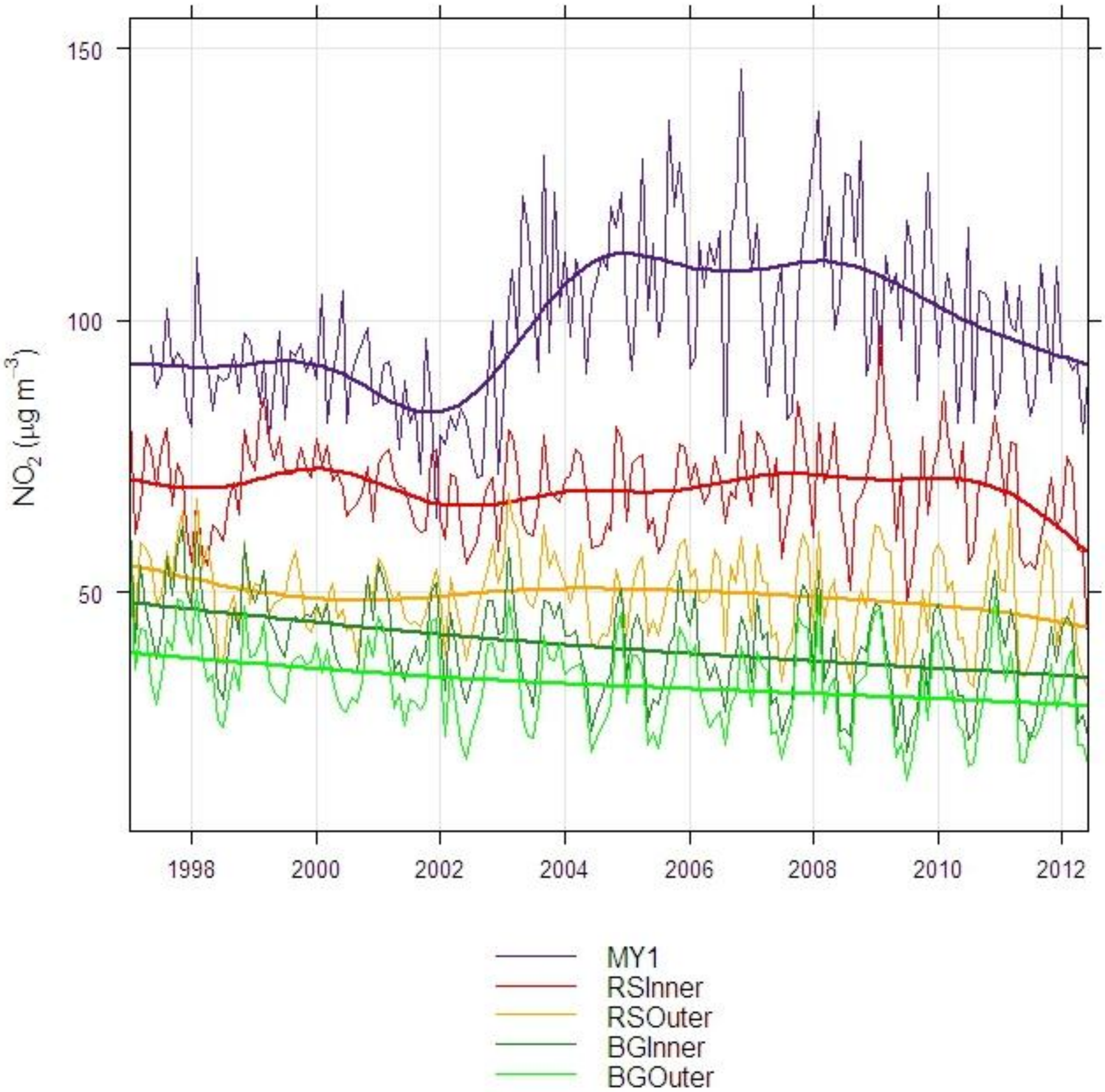

Figure 4 Monthly mean NO_2 concentrations at selected London monitoring sites. MY1 = Marylebone Road, RS= Roadside, BG = background, Inner and outer refer to inner and outer London.

Measured concentrations of NO_X and NO_2 in London were examined in detail by Beevers et al (2010) and compared to the expected changes from the progressive tightening of Euro emissions standards. It was found that NO_X and NO_2 concentrations were not responding as expected to the projected decreases in vehicle emissions. There has also been an increase in the proportion of NO_2 (relative to to NO_X) being directly emitted from newer diesel vehicles as highlighted Carslaw (2005) and by the UK Air Quality Expert Group (AQEG, 2007).

The work of Beevers et al (2010) was followed by an analysis of tests on approximately 72,000 vehicles by Carslaw et al (2011). It found that the progressive tightening of Euro standards had not been effective for diesel cars/vans and there had been little change in total NOx emissions over the past 15-20 years from these vehicle types. This may be partially explained by an increase in the power of diesel cars and that Euro 3–5 diesel cars can emit up to twice the amount of NOx under higher engine load conditions compared with older generation vehicles. This is possibly the result of the increased use of turbo-charging in modern diesel cars. There has also been an increase in the proportion of diesel vehicles sold since 2000.

NOx emissions from HGVs were static until Euro IV, when NOx decreased by about one third but the report raised questions regarding the emerging issue of the performance of selective catalytic reduction (SCR) used on HGVs which has been shown to be ineffective under urban-type (slow speed, low engine, temperature) conditions such as those prevailing in urban areas.

In contrast to diesel vehicles, NOx emissions from new Euro 5 petrol vehicles have reduced by 96% since pre-Euro (non-catalyst) vehicles, although older petrol vehicles (Euro 1-3) emit higher emissions of NOx than previously thought which may suggest that older petrol engine catalysts deteriorate faster than expected.

Despite their lower NO_X emissions the full benefit of petrol engine emissions control has been partially offset by a decrease the proportion of new petrol cars sold each year and the progressive increase of diesel vehicles. Petrol cars decreased from 86% in 2000 of new car sales to 48% in 2011 (SMMT, 2012). Incentivisation of small petrol and petrol hybrid cars may be a tool to tackle urban nitrogen dioxide.

PM_{10}

PM_{10} comprises of particles with different chemical composition from a variety of sources including primary emissions, secondary particles produced by chemical reactions in the atmosphere and particles from natural sources such as windblown dust and sea salt. There are two NAQS objectives for PM_{10} in line with the two EU Limit Values however the assessment method for the EU Limit Value allows several factors to be taken into account including the influence of natural sources. Of these natural sources sea salt is especially relevant to London. Other aspects of the assessment method mean that the final assessment of London's compliance with EU Limit Values for PM_{10} rests with Defra and cannot be interpreted directly from pollution measurements of the air that Londoners breathe.

The daily mean NAQS objective and the daily mean Limit Valve are the most stringent of the PM_{10} limits. These permit no more than 35 days per year with mean PM_{10} above 50 µg m^{-3}. The annual count of days with mean PM_{10} above 50 µg m^{-3} is shown in Figure 5. Two kerbside and three roadside monitoring sites measured more than 35 days. Some of the greatest concentrations of PM_{10} in London were measured in residential areas close to a small number of waste management sites. These are the focus of increased regulatory efforts by the Environment Agency and boroughs. The annual number of days with mean PM_{10} above 50 µg m^{-3} has decreased at the Neasden Lane (Brent) and Horn Lane (Ealing) industrial monitoring sites from 174 days and 205 days respectively during 2005.

Peaks in mean PM_{10} concentrations occur during prolonged periods of stable weather conditions. During wintertime pollution incidents PM_{10} in London can be dominated by London sources. High-pressure systems can also lead to the import of polluted air from elsewhere in the UK and Europe Alone or when combined with local pollution from London this can lead to days with mean PM_{10}

above 50 µg m^{-3}. New measurements of the chemical composition of PM in London are highlighting the importance of nitrate particles in the PM_{10} imported into London. These arise from emissions from both traffic and industry. Whilst control of these types of pollution episode may appear beyond London's control, this type of pollution episode was placed in its correct context during March 2012 when winds brought our own air pollution back to us demonstrating how our cities contribute to poor air pollution in areas over hundreds of kilometres away. Tackling local air pollution can improve the health of people who live near busy roads and decrease the impacts of each city on the wider region.

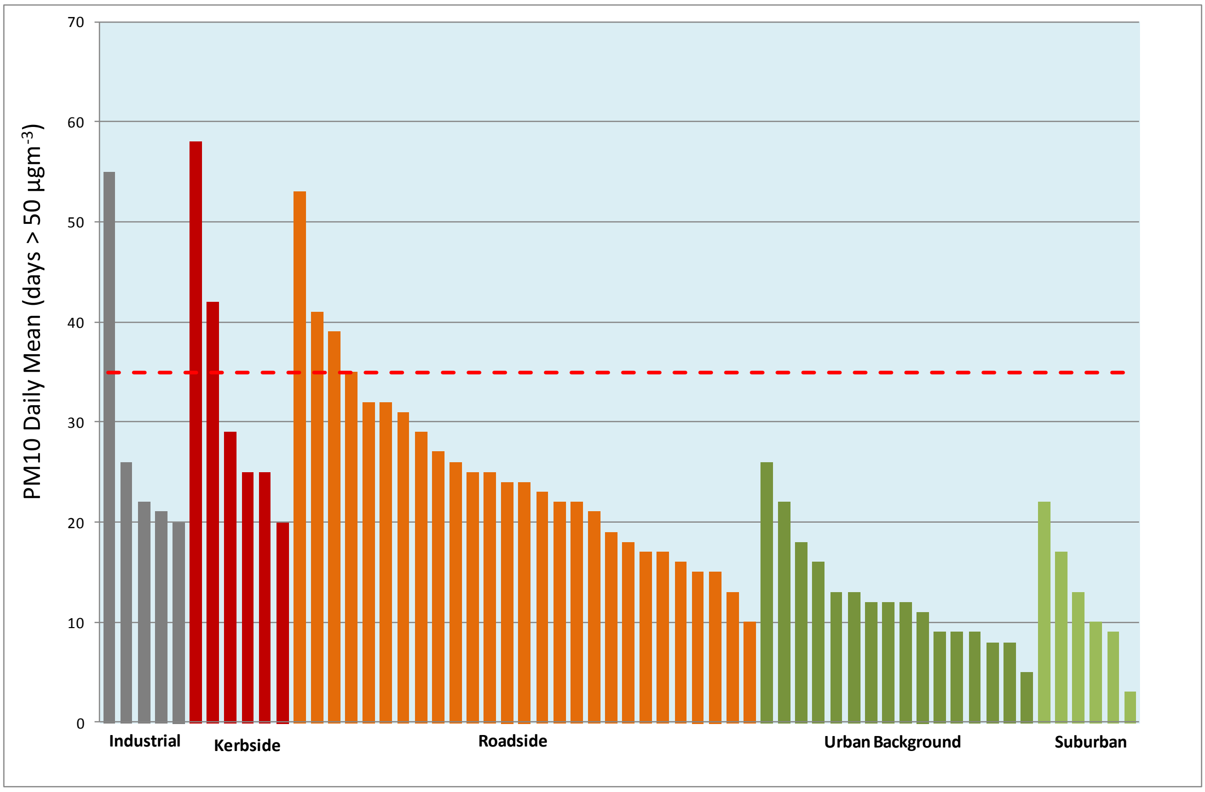

Figure 5 Number of days with mean PM_{10} > 50 ug m^{-3} LAQN sites during 2011. The NAQS objective is shown as broken red line and sites are grouped by type.

Measurement of PM_{10} presents many scientific and technical challenges. Consistent measurements to EU reference methodology date back to 2004 but the assessment of changes over time is complicated by the progressive updating of measurement equipment. Monthly mean concentrations of PM_{10} are shown in Figure 6. These suggest relative stability in PM_{10} concentrations across all site types. Further analysis would have to be undertaken to determine any actual underlying trend. Fluctuations in the measured concentrations at Marylebone Road are due to the variability at a single site whereas measurements from other locations represent composite measurements from several monitoring sites.

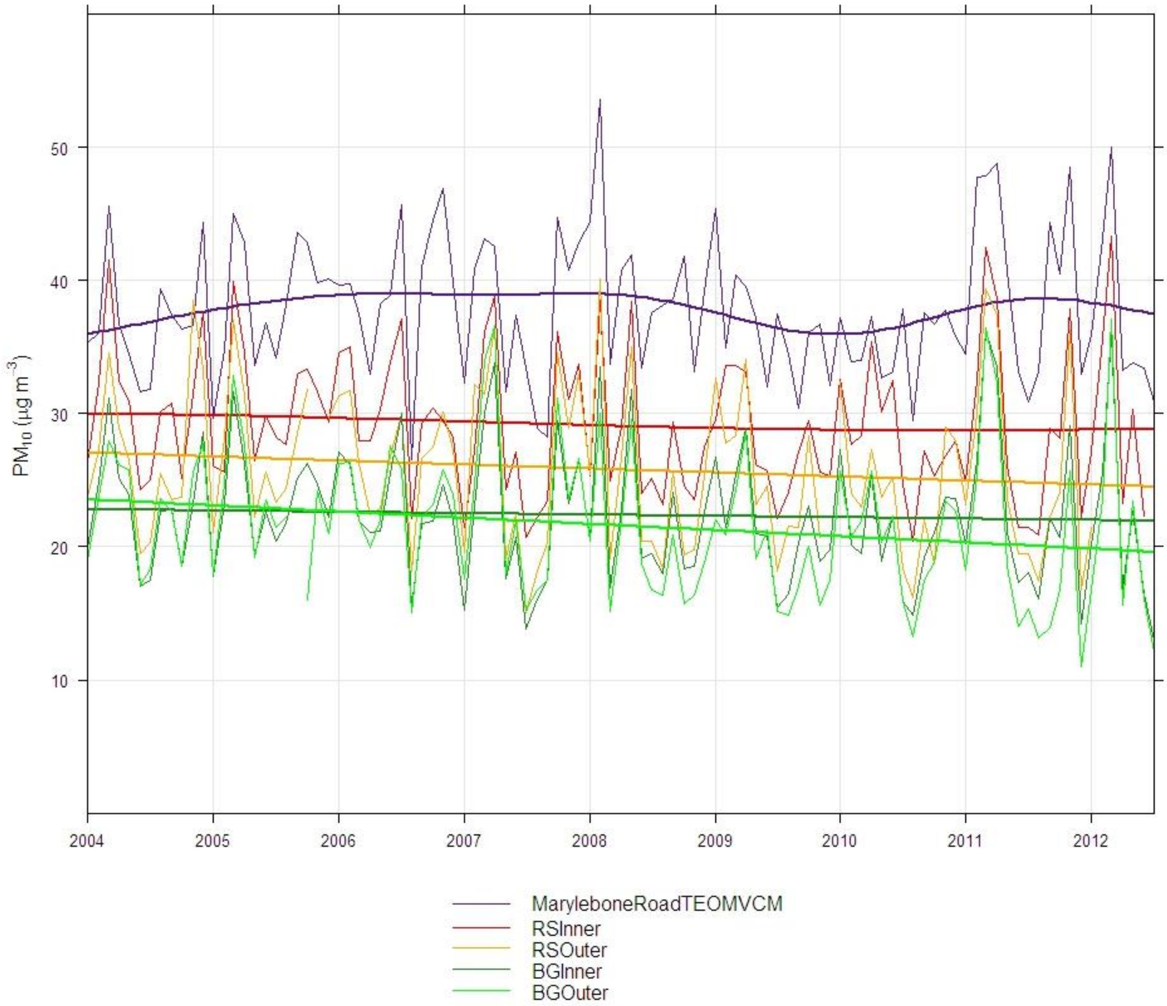

Figure 6 Monthly mean PM10 concentrations at selected London monitoring sites using the TEOM VCM method. RS= Roadside, BG = background, Inner and outer refer to inner and outer London.

There are several different ways to measure airborne particles and although the mass concentration is the regulatory method other metrics have been linked to health effects. From a toxicological perspective it has been suggested that the oxidative potential might best represent the challenge that PM provides to the lung. King's are an international leader in these measurements and several programmes are underway to determine the oxidative potential of London's PM including work under the TRAFFIC research project (see below). Measurements show greater oxidative potential in London when compared with rural areas and are greater close to roads in London (Mudway et al 2011).

It has also been suggested that the number of particles per unit volume of air may be linked to health effects. A study by Atkinson et al (2011) found that daily changes in particle number were associated with increased hospital admissions for cardiac problems. A large decrease in particle number has been found in London (and Birmingham) since late 2007 and this is thought to be due to the introduction of ultra-low sulphur diesel across the UK (Harrison et al 2012) as shown in Figure 7. It remains to be investigated if this change in particle number has been reflected in health data.

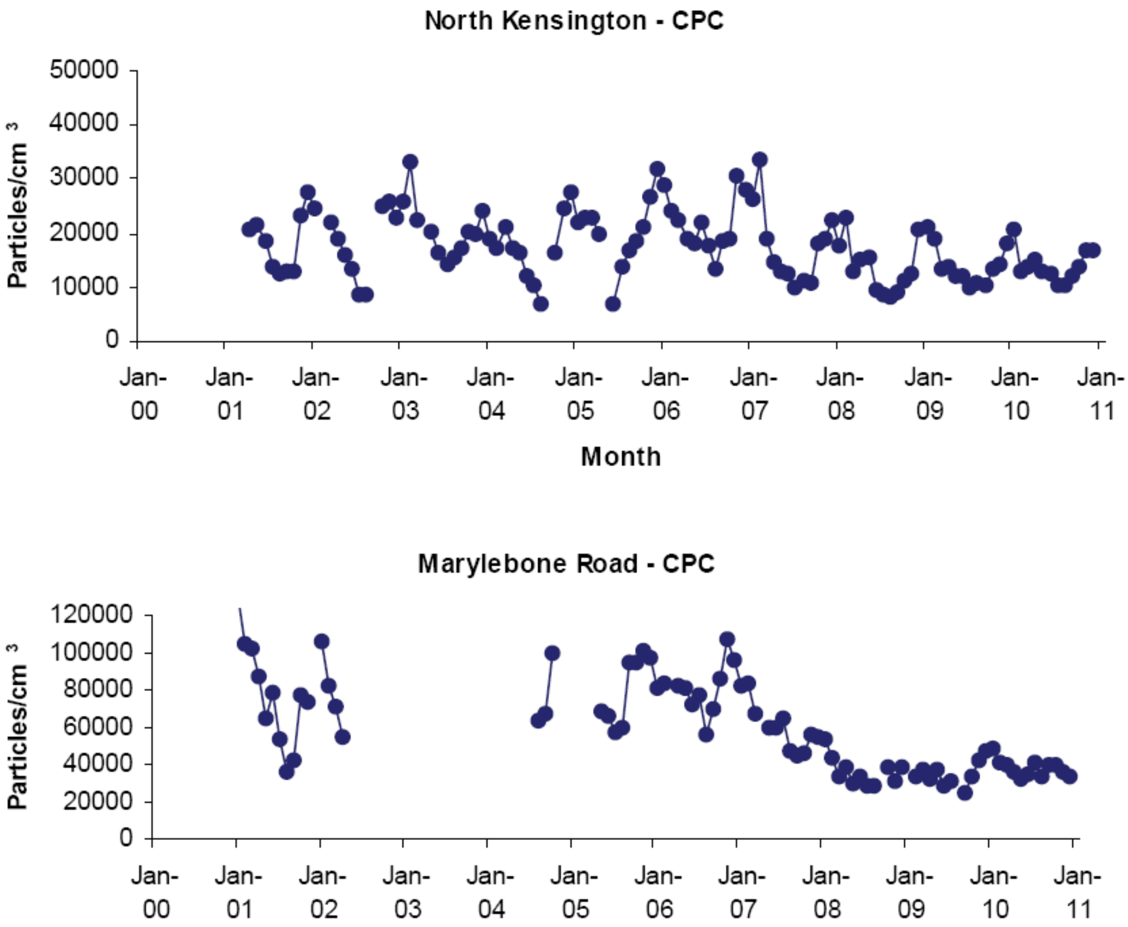

Figure 7 Monthly mean particle number concentration at the North Kensington background site and at Marylebone Road from Beccaceci et al 2011.

The London Low Emission Zone (LEZ)

The London Low Emission Zone was introduced in 2008 with further phases on 1st January 2012. Assessment of the effectiveness of the 2008 LEZ phases was undertaken at a set of so-called LEZ super sites funded by TfL and individual boroughs.

Figure 8 shows black carbon concentrations alongside four London roads along with $PM_{2.5}$ and from the nearby road itself. No clear decreases can be seen in PM_{10} concentrations but local concentrations of $PM_{2.5}$ and black carbon (an indicator for vehicle exhaust particles) showed decreases at sites in outer London on the North Circular and beside the Blackwall Tunnel north approach prior to the LEZ (indicating pre-compliance) and following the introduction of the scheme. The absence of clear changes in central London may reflect differences in the vehicle mix in central London with a smaller proportion of vehicles affected by the LEZ when compared with trunk roads in outer London.

There is a clear need for a detailed assessment of the implementation of phase 3 and 4 of the LEZ at the start of 2012.

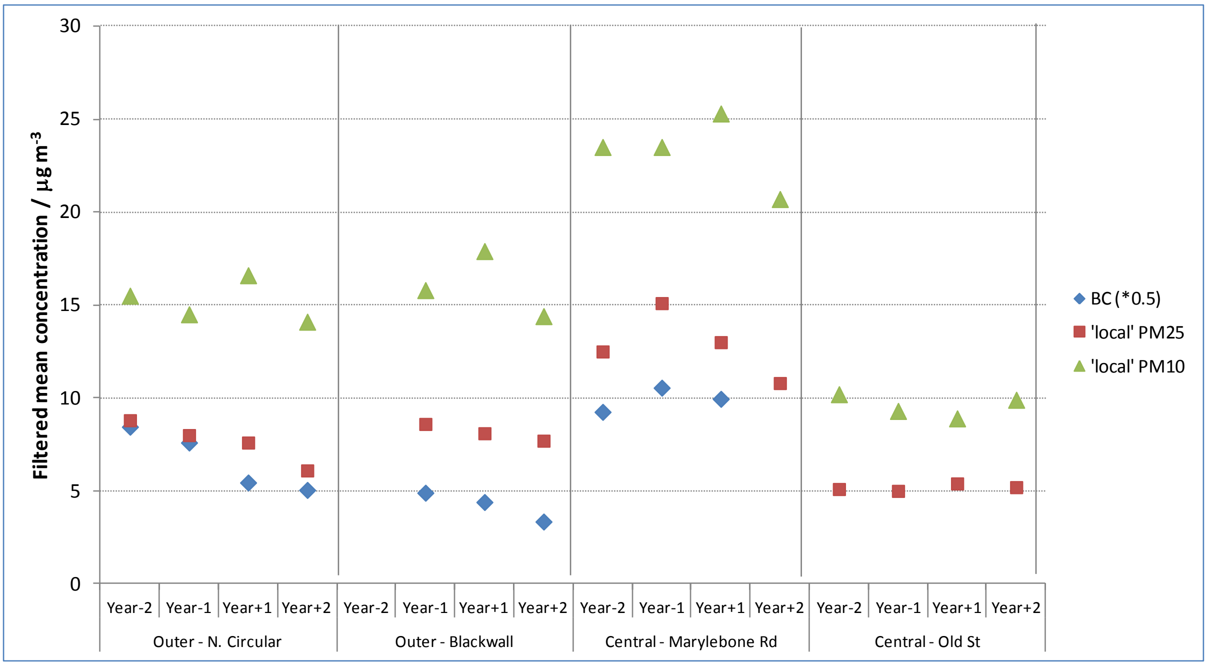

Figure 8 Annual concentrations of black carbon (BC) and $PM_{2.5}$ and PM_{10} from local sources in the years before and after the LEZ implementation in 2008.

New air pollution and health research in London

King's College London is taking a lead role in several new large scale research projects underway in London:

Roadside vehicle exhaust measurements:

Between 2007 and 2010 a programme of remote drive-by testing was carried out on approximately 72,000 vehicles and analysed by Carlsaw at al 2011. This included measurements within London in urban-type driving conditions to investigate why recent concentrations of NO_X and NO_2 in the UK have not decreased as anticipated. The analysis, funded by Defra highlighted that NO_X emissions from diesel vehicles, and diesel cars in particular, have not declined in line with the expectations from the introduction of pollution abatement equipment on new vehicles.

King's College London is leading a further programme of vehicle testing in London along with the University of Newcastle. The programme is funded by a Defra local authority grant with the City of London, Ealing and Southwark and aims to better characterise emissions from different vehicle types in real-world situations using unique experimental equipment from the University of Denver.

ClearfLo: Funded by the Natural Environment Research Council this project involves 11 UK universities and has made substantial investment air pollution monitoring sites alongside meteorological measurements to investigate pollution across London. The ambition of ClearfLo is to provide long-term integrated measurements of the meteorology, composition and particulate loading of London's urban atmosphere, made at street level and at elevated sites, complemented by modelling to improve predictive capability for air quality.

TRAFFIC: The Traffic and Air Pollution in London project is funded by a £2million grant under the cross-Research Council Environmental Exposure and Health Initiative (EEHI) with funds from the Natural Environment Research Council (NERC), the Medical Research Council (MRC), and the Department of Health (DoH). King's are leading a consortium of over 20 investigators from Imperial College London, St George's, University of London and The London School of Hygiene and Tropical Medicine. The project will run from 2011 to 2014 inclusive.

The first part of the study is concerned with detailed measurements of air pollutants with chemical analyses of particles to investigate their toxicity and sources.

This will include linking these results to daily data from registries of deaths and hospital admissions to study which mixtures and sources of particles are most likely to have adverse effects. It will be one of the first studies to link epidemiological analyses to laboratory analyses in this way.

The second part is the development of models of exposure to air pollution which draw on information about concentrations, emissions and time-activity. This includes a novel approach using anonymous Oyster card information and/or GPS on mobile phones, which will then be analysed alongside pollution measurements to create a mathematical model. This model will provide a way of investigating the effects of various policy scenarios on actual exposure of population sub-groups. It will provide a guide to enable people to adapt their journeys if desired and where possible to reduce their exposure to harmful vehicle emissions. Lastly, it will improve the estimation of exposure for health studies which generally rely only on concentrations at the postcode or address level.

The third main component is to investigate the association between long term exposure to traffic pollution, indicated by concentrations at address or postcode, and a range of potential health effects from cradle to the grave.

These include effects on children's health and risk factors for future cardiovascular disease, adverse reproductive outcomes (low birthweight and pre-term delivery), primary care data on disease and consultations, the incidence of heart attacks, hospital admissions and mortality. This will be the first study to bring all these outcomes together in a coordinated way and with the explicit aim of developing exposure-response relationships for use in health impact assessments.

EXHALE: Funded by the National Institute for Health Research's comprehensive Biomedical Research Centre (BRC), this project will investigate the impact of the LEZ on children's respiratory health.

Specifically, the project will assess whether the reduction in exposure to traffic emissions resulting from the LEZ will be associated with improvements in lung function. The study focuses on children in East London, as the LEZ is predicted to have a significant impact on air quality in this area.

The study involves conducting health assessments in 8 to 9 year-old children at selected schools in Tower Hamlets and Hackney. The assessments include measurements of respiratory health, biomarkers of exposure to traffic-related air pollution, genetic susceptibility to the effects of air pollution, and systemic response to air pollution.

The health data is then linked to modelled air quality data, provided by Kings' modelling team, to provide a comprehensive picture of the effects of traffic-related air pollution on children's health, and the impact of the LEZ on this. The study will last for 4 years, with health assessments conducted each winter. As of June 2011, King's have completed 3 years of data collection, and over 1000 children from 23 schools have participated.

As part of the study, scientists from King's provide a morning of education for the Year 4 class at each school visited, teaching students about the science and history of air pollution. This year, King's have also been working with a professional artist, Effie Coe, as part of the Invisible Dust project. Effie has designed art activities specifically to help the children understand and visualise the scientific concepts they are learning. The video below was made at one of our most recent school visits and shows the health assessments, as well as some of the teaching activities in the classroom.

The study is a collaborative project between members of the Environmental Research Group at King's College London, and the Centre for Health Sciences at Barts and the London School of Medicine and Dentistry.

Improved air pollution information for Londoners

The 2011 House of Commons Environmental Audit Committee's 2011 report on air quality concluded that, "A public awareness campaign would be the single most important tool in improving air quality. It should be used to inform people about the positive action they could take to reduce emissions and their exposure."

The new UK Daily Air Quality Index was launched by Defra at the start of 2012. The index is used to communicate information about real-time pollution exposure and to forecasts of expected levels of air pollution for the public. The new index includes $PM_{2.5}$ for the first time and is supported by revised health advice. With advanced warning of poor air quality, individuals who are sensitive to the effects of air pollution can have the opportunity to modify their behaviour to reduce the severity of their symptoms.

In addition to national air quality information from Defra, London has the most advanced air quality information systems of any city in Europe.

Innovatively this includes the LondonAir free smart phone application which allows users to access air pollution information on the move. Users can also subscribe without charge to be notified of air pollution at their local monitoring site or when a pollution threshold has been breached. Designed and developed by the monitoring team at King's the new iPhone application gained over 6000 subscribers during its first two weeks and peaked at over 13,000. During the Easter 2011 pollution episodes King's sent out over 400,000 pollution notifications to iPhone subscribers.

The LondonAir site is the prime source of air pollution information for the capital. During pollution incidents, several thousand visitors per day view the latest pollution concentrations which are updated each hour. The website was re-designed in 2011 following consultations with regular users of the site. This includes a guide, revised to adopt an accessible style and incorporate additional information on health and the latest research. The LondonAir website also includes videos for eleven important topics, interviewing experts on the subject. A mobile version of the website allows people to access air pollution levels at any time and place, and complements the LondonAir smart phone applications. The LondonAir website and smartphone applications will be updated during July ahead of the London Olympics to provide specific information for Games visitors. Additional air quality information is provided on both Facebook and hourly updated Twitter feeds.

The long-standing AirTEXT service continues to provide SMS air pollution forecasts and will be shortly launching a smartphone application.

References

Air Quality Expert Group (AQEG), 2007. Trends in primary nitrogen dioxide in the UK. Defra, London. Available at: http://archive.defra.gov.uk/environment/quality/air/airquality/publications/primaryno2-trends/documents/primary-no-trends.pdf

Atkinson, R.W., Fuller, G.W., Anderson, HR., Harrison, RM., Armstrong. B., 2010. Urban ambient particle metrics and health, a time-series analysis. Epidemiology 21, 501-511.

Beccaceci, S. , Muhunthan, D. , Sarantaridis, D., Tompkins, J.., Butterfield, D., Quincey, P., Brown,R., Green, D., Grieve, A., Fuller, G. 2011. CPEA 28: Airborne Particulate Concentrations and Numbers in the United Kingdom (phase 2) Annual report 2010. National Physical Laboratory, Teddington.

Beevers, S., Carslaw, D., Westmoreland, E., and Mittal, H., 2009. Air pollution and emissions trends in London. King's College London available at http://uk-air.defra.gov.uk/reports/cat05/1004010934_MeasurementvsEmissionsTrends.pdf.

Carslaw, D.C. 2005. Evidence of an increasing NO2/NOX emissions ratio from road traffic emissions. Atmospheric Environment, 39(26) 4793-4802.

Carslaw, D., Beevers, S. Westmoreland, E. Williams, M. Tate, J. Murrells, T. Stedman, J. Li, Y., Grice, S., Kent, A. and I. Tsagatakis. 2011. Trends in NOx and NO2 emissions and ambient measurements in the UK. King's College London available at http://uk-air.defra.gov.uk/reports/cat05/1103041401_110303_Draft_NOx_NO2_trends_report.pdf.

Jones, A. M., Harrison, R.M., Barratt, B., Fuller, G., 2012. A large reduction in airborne particle number concentrations at the time of the introduction of "sulphur free" diesel and the London Low Emission Zone. Atmospheric Environment 50, 129-138.

Mudway, I.S., Fuller, G., Green, D., Dunster, C., and Kelly, F. J., 2011. Quantifying the London Specific Component of PM10 Oxidative Activity. King's College London available at http://uk-air.defra.gov.uk/reports/cat05/0607051333_Comparing_the_toxicity_of_PM_collected_using_different_sam..pdf.

Society of Motor Manufactures and Traders (SMMT) 2012. New Car CO2 Report 2012. The 11th report. SMMT, London available at http://www.smmt.co.uk/wp-content/uploads/SMMT-New-Car-CO2-Report-2012.pdf