King's College London

Environmental Research Group

PM_{10} Source Apportionment at Brent 5 Neasden Lane

April 2007

Title	PM_{10} source apportionment at Brent 5, Neasden Lane

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1. Summary

The Brent 5 monitoring site is located on Neasden Lane opposite the entrance to several waste transfer businesses that share Neasden Goods Yard. This report compares measured concentrations at the site to the Air Quality Strategy Objectives and quantifies the sources of PM_{10} that affected the monitoring site during the period 1st March 2004 to the end of 2005.

PM_{10} concentrations at the site are amongst the greatest concentrations measured in London. During 2005 the site measured 180 days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3. This is a substantial breach of the Air Quality Strategy (AQS) Objective / EU Limit Value of 35 days per year. The site also measured an annual mean PM_{10} concentration of 62 μgm^{-3} TEOM*1.3, exceeding the 40 μgm^{-3} TEOM*1.3 AQS Objective / EU Limit value.

To understand the sources of PM_{10} affecting the site an apportionment technique was used. The source apportionment model divided the measured concentration of PM_{10} into the following sources:

- Background secondary and natural: background PM_{10} that is not linked to NO_X.
- Background primary: background PM_{10} that is linked to NO_X.
- Local primary: PM_{10} estimated from the elevation in NO_X concentration, above background. This source includes both primary tail pipe PM_{10} and also expected PM_{10} from resuspension, tyre and brake wear sources.
- Local – other: PM_{10} not accounted for by the model. This includes local sources that are not linked to NO_X and also the local sources that may be linked to NO_X but were not expected on the basis of NO_X and PM_{10} relationships derived from other sites in London and the south east, abnormal quantities of resuspended particulate for example.
- TEOM offset - the measurement offset of +3 μgm^{-3} (raw TEOM) applied by the TEOM to all measured mass concentrations.

The uncertainty associated with the calculation of the local – other PM_{10} was assessed using the GUM (Guide to the Expression of Measurement Uncertainty in Measurement) approach (ISO, 1995).

Overall the source apportionment model performed well at each of the 6 test sites.

Source apportionment indicated that 53 (+/- 6, 2σ) % of the PM_{10} measured at the site came from local – other sources. In the absence of this source the site would very likely have achieved the AQS Objective / EU Limit Value during 2005. The annual mean AQS Objective could have been achieved in 2005 with a reduction of 70 (+/- 4, 2σ) % in the mean concentration of local – other PM_{10}. The daily mean AQS Objective could have been met in 2005 with a reduction of around 90% in the mean concentration of local – other PM_{10}.

The local – other PM_{10} source dominated the measured PM_{10} concentrations at the site during working hours on weekdays and during Saturday mornings. It is likely that the local – other PM_{10} also originates from vehicle activity both within the yard and on Neasden Lane through the resuspension of silt from the road surface or suspension of material from 'dusty' vehicles.

The Brent 5 monitoring site provides accurate measurements of the PM_{10} concentrations experienced opposite the entrance to Neasden Goods Yard, and close to nearby housing, however it does not provide information about the extent of the area affected by these concentrations. Based on studies at similar sites, it is likely that the area exceeding the Objective extends at least 500 to 1000 m along haul routes from Neasden Goods Yard. Although no evidence of fugitive sources of local – other PM_{10} was detected at the Brent 5 site, we cannot rule out fugitive sources affecting receptors outside the Neasden Goods Yard boundary.

It is recommended that:

- The findings of this report should be incorporated into the Council's Air Quality Action Plan.
- The Council should work together with the Environment Agency and operators within Neasden Goods Yard to reduce the silt deposited on Neasden Lane. Determining the cause of the apparent seasonality in the concentration of local – other PM_{10} may assist this process.
- The Council should continue to monitor concentrations of NO_X and PM_{10} to assess the concentration reductions achieved by abatement measures. It should however be recognised that the day to day variation in the concentration of local – other PM_{10} and the apparent seasonality may confound this assessment in the short term. This source apportionment study should be repeated periodically to quantify changes in local – other PM_{10}.
- A further monitoring site should be installed further along Neasden Lane to determine the reduction of local – other PM_{10} with distance from the Goods Yard entrance. This would enable emission factors for the local – other PM_{10} to be determined and the area affected could be estimated using dispersion modelling.
- Further monitoring should be considered close to any residential areas on the boundary of the Goods Yard to determine the affect of any fugitive sources.

2. Introduction

This report is intended to assist Brent Council with its continuing local Air Quality Management duties.

The report provides a detailed analysis of air pollution measurements made at the Brent 5 monitoring site, which was located on Neasden Lane, opposite the entrance to several waste transfer businesses that share Neasden Goods Yard. The report compares measured PM_{10} concentrations to the UK Air Quality Strategy Objectives and quantifies the sources of PM_{10} that affected the monitoring site.

The report presents the analysis of measurements made from 1st March 2004 to the end of 2005, a period of 671 days, which includes the first full calendar year of measurements.

Previous Air Quality Assessments

As part of its Local Air Quality Management (LAQM) responsibilities, Brent Council completed the previous rounds review and assessment (R&A) of air quality (see the individual reports prepared between 1999 and 2006). These reports presented a staged approach whereby the seven air pollutants in the Government's Air Quality Strategy related to LAQM, were assessed and screened within the Council's area.

Areas across the Borough were found to exceed the NO_2 annual mean objective and 24 hour mean PM_{10} objective, mainly relating to roads. As a consequence an Air Quality Management Area (AQMA) was designated for both pollutants for part of the Borough. The AQMA includes the entire area south of the North Circular Road and all housing, schools and hospitals along the North Circular Road, Harrow Road, Bridgewater Road, Ealing Road, Watford Road, Kenton Road, Kingsbury Road, Edgware Road, Blackbird Hill, Forty Lane, Forty Avenue and East Lane.

The Council completed its third round Updating and Screening Assessment (USA) of the seven Local Air Quality Management (LAQM) pollutants during March 2006 (KCL 2006). The USA findings for particles (PM_{10}) highlighted that the PM_{10} concentrations at Brent 5 beached both of the Air Quality Strategy Objectives by a wide margin and it was recommended that a Detailed Assessment be undertaken.

This report provides detailed quantification and characterisation of the air pollution sources affecting Brent 5 to inform the detailed assessment process.

Reports and other material related to the Council's air quality management responsibilities can be found on the Council's web site at:

http://www.brent.gov.uk/ehealth.nsf/97adad6ff206607c8025663c0065c536/e8b77641552a8ffc8025682700581c80!OpenDocument

3. The site

The Brent 5 monitoring site is located at a roadside location on the east side of Neasden Lane opposite the entrance to Neasden Goods Yard, which contains several waste transfer facilities. Neasden lane runs northwest from the site to Neasden station. To the south Neasden Lane runs under a railway bridge before turning south through a residential area. The distance between the monitoring site and the road is similar to that of the nearby housing which is less than 50m from the monitoring site.

Figure 1 Aerial photograph of Neasden Goods Yard. The location of the Brent 5 monitoring site is indicated by a red arrow.

4. Site visits

A site visit was undertaken prior to the installation of the Brent 5 monitoring site on the 3rd October 2003. The activities within each waste facility and vehicle movements were observed. Substantial road silting was seen on the access road, up to 2 cm deep and further road silting was observed tracking from the waste sites access along Neasden Lane. Silting in Neasden Lane is shown in Figure 2.

Further visits were undertaken by KCL during 2004 and 2005 in conjunction with the operation of the measurement site. These confirmed the continued road silting.

Figure 2 Road silting outside housing in Neasden Lane 3rd October 2003. The location of the monitoring site is indicated by a red arrow.

Figure 3 Vehicles entering and leaving Neasden Goods Yard (photos Jennifer Barrett LB Brent).

5. Method

Air pollution measurements

Air pollution monitoring equipment was installed on the east site of Neasden Lane opposite the access road to the waste faculties. The site became operational on the 29th February 2004. The sample inlet was approximately 2m above the ground and 5m from the kerb line. The distance of the site from the kerb line is similar to that of nearby residential properties along Neasden Lane.

Automatic measurements of PM_{10} were made using the Tapered Element Oscillating Microbalance (TEOM) method. Measurements of NO_X used in this study were made using the chemiluminescent method with automatic equipment subject to fortnightly calibration traceable to National Metrological Standards. All measurements were logged by the instruments themselves and collected by KCL each hour. Measurements from the monitoring site were validated by KCL using the most up to date calibration factors and disseminated in near real time on the LAQN web page (www.londonair.org.uk).

The NO_X and PM_{10} instruments were subject to UKAS accredited audit by the National Physical Laboratory (NPL) twice yearly.

A final measurement data set for March 2004 to the end of 2005 was produced by KCL following retrospective ratification of the measurements using procedures, which exceed the requirements detailed in LAQM TG03 (DEFRA, 2003) and the latest guidance released in 2006. During ratification information from regular calibrations, audits and daily manual validation were used to establish an operational and calibration history of the instruments and the pollution measurements were corrected to establish traceability to National Metrological Standards. Details of the monitoring site and the final dataset may be found at www.londonair.or.uk and specifically at:

http://www.londonair.org.uk/london/asp/publicdetails.asp?region=0&site=BT5&postcode=&details=&mapview=all&network=All

The EU limit value requires PM_{10} to be measured using the gravimetric method. However, the vast majority of PM_{10} measurements in and around London are made using TEOMs. Allen et al., (1997); Smith et al., (1997); Green et al., (2001); Charron et al., (2004) and others have observed that the TEOM produced a lower measurement of PM_{10} than that derived gravimetrically due to greater sampling losses of semi-volatile particulate and particle bound water from the TEOM. A 'correction' factor of 1.3 is recommended in the UK for comparison of TEOM PM_{10} measurements with the EU Directive (DETR, 1999). It is recognised that the 'correction' factor will depend on PM_{10} particle composition (Charron et al., 2004) and this is therefore likely to lead to inaccuracies when applied to PM_{10} from different sources and to different size fractions of airborne particulate. The application of a consistent 1.3 factor to PM_{10} from all sources is however required to ensure consistency between measured concentrations and the model results and to allow both to be compared to the EU Limit Values and AQS Objectives.

PM_{10} Source apportionment methodology

The PM_{10} modelling methodology described in Fuller et al., (2002) divided PM_{10} by source through analysis of measurements of annual mean NO_X, PM_{10} and $PM_{2.5}$ across a network of monitoring sites. Similar source apportionment techniques have been applied elsewhere in the UK and to a lesser extent in Europe (Deacon et al., 1997; Harrison et al., 1997; APEG 1999; Kukkonen et al., 2001 and Stedman et al., 2001).

Fuller et al., 2002 identified PM_{10} as arising from three source components: primary (associated with NO_X), secondary (mainly the $PM_{2.5}$ not associated with NO_X) and natural (coarse component not associated with NO_X). The model assumed that the secondary and natural components do not vary across the London region (over distances of around 100 km) for medium term averaging periods, a day or more. The total PM_{10} at any monitoring site was therefore a combination of the regional secondary and natural PM_{10} with an additional local primary component from combustion sources. The local primary component from combustion sources was determined from the local NO_X concentration.

The KCL model has been successfully employed elsewhere to determine PM_{10} arising from local non-vehicle sources including building works, road works (Fuller and Green 2004) and an industrial process (Fuller and Tremper 2004). The model has also been successfully applied to source apportion PM_{10} arising in the vicinity of waste handling facilities (Fuller and Baker 2001).

This modelling exercise deployed the model in a simplified form where the secondary and natural components were not separated and therefore the co-located measurements of $PM_{2.5}$ required by the full method were not needed. To model the PM_{10} concentration at Brent 5 the concentration of the regional secondary and natural components was derived from five background LAQN monitoring sites. These five background / suburban monitoring sites (termed base sites) were selected because of their proximity to Brent 5 and their freedom from local non-NO_X sources of PM_{10}. The base sites are listed in Table 2.

Local events that are not associated with NO_X will not be predicted by this model since it has no knowledge of them. Using the approach employed in Fuller and Green (2004) the difference between measured and modelled PM_{10} enabled the quantification of the PM_{10} arising from local sources that were not sources of NO_X. In this study this approach is used to identify both local sources that are not sources of NO_X and local sources that may be linked to NO_X that are not expected on the basis of NO_X and PM_{10} relationships derived from other sites in London and the south east.

Model Inputs and Outputs

The model was applied separately to measurements of NO_X and PM_{10} which were averaged in three ways to look at possible characteristics of the local PM_{10} source at Brent 5. The following model inputs (and therefore outputs) were chosen:

- Daily mean concentrations for comparison to the EU Limit Value and to identify the dates on which local PM_{10} incidents occurred. Daily mean concentrations of NO_X and PM_{10} were calculated from 15 minutes mean measurements for each day with a daily data capture of greater than 75%.

- Mean concentrations averaged by day of week and hour of day to determine any pattern in concentration of the local non-NO_X PM_{10} source(s). For instance the mean NO_X and PM_{10} measurements for each Wednesday at 13 h were averaged as input data, followed by each Wednesday at 14 h and so on.

- Mean concentrations averaged by wind direction, to create pollution roses, to identify the direction of local PM_{10} source(s), relative to the Brent 5 site. The selection of appropriate wind direction measurements for Brent 5 is discussed below. Care should be taken when interpreting the results of this analysis since equal weighting is given to the concentration measurements in each 10 degrees averaging bin. However the wind does not blow with equal frequency from all directions. The apportionment from this analysis cannot therefore be compared directly to the overall apportionment, apportionment of daily mean concentration or that undertaken with respect to day of week and hour of day.

In each case appropriately averaged measurement at the base sites were apportioned between primary and non-primary sources. To undertake this apportionment, the concentration of primary PM_{10} was calculated using the NO_X concentration at each base site and regression gradients as described in Fuller et al., (2002). The modelled total PM_{10} at Brent 5 and at the test sites was then calculated by adding the mean non-primary PM_{10} from the base sites to the primary PM_{10} calculated from NO_X measurements from each site.

The source apportionment technique divided the measured concentration of PM_{10} into the following sources:

- **Background secondary and natural** – background PM_{10} that is not linked to NO_X

- **Background primary** – background PM_{10} that is linked to NO_X.

- **Local primary** – PM_{10} estimated from the elevation in NO_X concentration, above background. This source includes both primary tail pipe PM_{10} and also expected PM_{10} from resuspension; tyre and brake wear sources determined from average conditions throughout the LAQN, as determined from network wide regressions. PM_{10} emissions from any diesel trains should also be associated with NO_X and would be included within this source category.

- **Local - other** – PM_{10} not accounted for by the model. This will include local sources that are not linked to NO_X and also the local sources that may be linked to NO_X but were not expected on the basis of NO_X and PM_{10} relationships derived from other sites in London and the south east, abnormal quantities of resuspended particulate for example.

- **TEOM offset** - the measurement offset of +3 μgm^{-3} (raw TEOM) applied by the TEOM to all measured mass concentrations (Patashnick and Rupprecht (1991, 1992, 1996), Rupprecht and Patashnick Co. Inc. (1992), Rupprecht and Patashnick Co. Inc. (1996)) was included as another 'source' within the apportionment scheme. Following the application of the 1.3 'correction' factor this offset had a value of 3.9 μgm^{-3}. Retention of the offset within the model ensured comparability between the source apportionment method and TEOM measurements and enabled the source apportioned TEOM measurements to be compared to the EU Limit Value

Wind direction measurements

Pollution roses show the mean concentration of pollution averaged according to wind direction.

PM_{10} pollution roses were calculated using mean NO_X and PM_{10} concentration averaged for each 10 degrees wind sector. Wind direction is not a scalar quantity but is related to the wind vector. For this reason vector averaged 15 minutes wind direction measurements were used along with contemporaneous pollution measurements.

Wind direction measurements were not available at the Brent 5 site. Wind direction measurements were therefore taken from the nearby Brent 1. The ability of the wind direction measurements at Brent 1 to represent those over a wider area were tested by comparing Brent 1 measurements for during the middle of the study period (January to March 2005) to those made at Ealing 7 and Bexley 2 monitoring sites. Excellent agreement was found between the wind direction measurements at Brent 1 and Ealing 7. The agreement between Brent 1 and Bexley 2 was also good. These tests confirmed the ability of the measurements at Brent 1 to represent wind direction over a wider area.

Uncertainty Estimates

The method of calculating the local – other PM_{10} relies on the difference between measured and modelled PM_{10}. This difference may however also be artefacts arising from uncertainty in the measurement and modelling process.

The uncertainty associated with the calculation of the local – other PM_{10} was assessed using the GUM (Guide to the Expression of Measurement Uncertainty in Measurement) approach (ISO, 1995).

The GUM approach requires a measurement equation to link the output quantity with the various input quantities and then provides a methodology to link the uncertainty in the inputs to the uncertainty in the output. The GUM approach provides two methods for estimating the uncertainty associated with each input quantity: type A estimates from statistical analysis and type B estimates from other methods (e.g. instrument specifications). The data sources for the uncertainty estimates of each of the model inputs are listed Table 1.

Input Source	Source for input uncertainty	Type
TEOM measurement of PM_{10}	Lampert (1998)	B
NO_X measurement	KCL (2002)	B
Ratio of NO_X to primary PM_{10} concentration	RMA regression of annual mean concentrations from 82 monitoring sites in London and SE see Fuller and Green (2006).	A
Background secondary and natural PM_{10}	Standard deviation of estimates from 5 sites	A

Table 1 Sources for input uncertainty.

The GUM approach assumes that the estimates of the uncertainty associated with each input quantity are considered to be normally distributed about the value of the input quantity. They are therefore approximated as statistical variances and are characterised by their standard deviation. The uncertainty in the input quantities are combined as variances, along with sensitivity coefficients determined from the partial derivative of the measurement equation, with respect to each of the input quantities, to derive a combined standard uncertainty. Additional terms in the calculation of the combined standard uncertainty are required if input quantities are correlated. Finally, the combined standard uncertainty is multiplied by a coverage factor (k) to approximate to a required confidence interval expressed as a number of standard deviations. A k value of 2 was chosen to approximate to a 95% confidence interval.

Implementation of the GUM uncertainty analysis involved creation of an uncertainty model that was 'run' in parallel to the main model and produced estimates for the uncertainty of each output result. In this way a separate uncertainty estimate was available for each model output e.g. daily mean concentration, diurnal average etc.

In addition to using the GUM model to estimate model uncertainty, the model was also used to predict PM_{10} at six test sites in addition to Brent 5. The modelled concentrations and estimated uncertainty at the test sites were used to check the validity of the GUM uncertainty estimates and to check for significant model bias. The test sites were selected as the closest roadside sites to Brent 5. The tests sites are listed in Table 2. Further details of the monitoring sites used in the study can be found on the LAQN web site at www.londonair.org.uk

Site name	Site type
Base Sites	
Barnet 2	Urban background
Ealing 7	Urban background
Hammersmith & Fulham 2	Urban background
Harrow 1	Urban background
Kensington & Chelsea 1	Urban background
Richmond 2	Suburban
Test Sites	
Brent 3	Roadside
Brent 4	Roadside
Ealing 2	Roadside
Harrow 2	Roadside
Hounslow 4	Roadside
Richmond 1	Roadside

Table 2 Base and test sites used in the source apportionment model

Additionally a sensitivity test was carried out to assess the impact of assuming a worst tail pipe PM_{10} emissions scenario. Emissions rates for HGV vehicles (both fixed and articulated) were examined to determine the highest feasible NO_X : primary PM_{10} emissions ratio. This was then used as a model input instead of the NO_X : primary PM_{10} concentration ratio determined from measurement sites across London and SE England.

6. Results and discussion

Air pollution measurements 2005

Air pollution measurements from the Brent 5 monitoring site are shown in Table 3. Table 3 also shows measurements at the nearby base and test sites. For additional comparison measurements from 2 industrial roadside sites (type 'I' in Table 3) close to waste transfer facilities are also shown along with measurements from the Marylebone Road kerbside site. Measurements from all sites are shown for 2005 and were fully ratified.

Table 3 is ordered by PM_{10} concentration and clearly indicates the concerns regarding the PM_{10} concentrations at the 3 sites close to waste facilities. Each of these sites exceeded the short-term EU Limit Value during this period (35 days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3). The EU Limit Value was also exceeded at the Marylebone Road kerbside site and at the Brent 4 roadside site. Both Marylebone Road and Brent 4 are alongside major roads. The source apportionment scheme in Fuller et al. (2002), suggests that primary PM_{10} emissions are linked to NO_X and thus high levels of PM_{10} would be expected at Marylebone Road and Brent 4. Such an explanation does not account for the PM_{10} concentrations measured at Brent 5 and Bexley 4 and thus a non tail pipe source of PM_{10} is obviously affecting these sites.

Site	Type	PM_{10} Capture %	μgm^{-3} TEOM*1.3 Mean	μgm^{-3} TEOM*1.3 Daily mean > 50	NO_X Annual mean μgm^{-3}
Ealing 8	I	84	84	230	-
Brent 5	I	96	62	180	127
Marylebone Rd	K	96	43	118	293
Bexley 4	I	98	44	105	71
Brent 4	R	91	43	86	277
Hounslow 4	R	99	30	25	171
Ealing 2	R	89	29	20	137
Harrow 2	R	97	29	18	119
Brent 3	R	83	30	17	112
Barnet 2	U	98	24	8	64
H'smith and Fulham 2	U	97	24	6	64
Kens and Chelsea 1	U	99	24	6	66
Richmond 1	R	99	26	6	84
Ealing 7	U	95	23	5	56
Richmond 2	S	99	22	4	51
Brent 1	S	83	21	3	56
Harrow 1	U	99	20	1	42

Table 3 Measurements of air pollution at Brent 5 and nearby sites during 2005. Measurements are ordered by the number of days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3.

Type: I = Industrial roadside, K= kerbside, R = roadside, U = urban background, S = suburban.

Comparison of measured and modelled concentrations

Measured and modelled annual mean PM_{10} concentrations for Brent 5 and each of the roadside test sites are shown in Figure 4. Overall the model performed well at each of the 6 test sites with measured concentrations close to model predictions and within the uncertainty estimates. The model exhibited a slight positive (but non-significant) bias of 5 % mainly due to the modelled concentrations at Hounslow 4. This would result in a commensurate under estimate in the concentration of PM_{10} from local – other sources. Measured annual concentrations at Brent 5 however exceeded the modelled concentrations by 33 µg m^{-3} TEOM*1.3, a margin that greatly exceeded the uncertainty estimates.

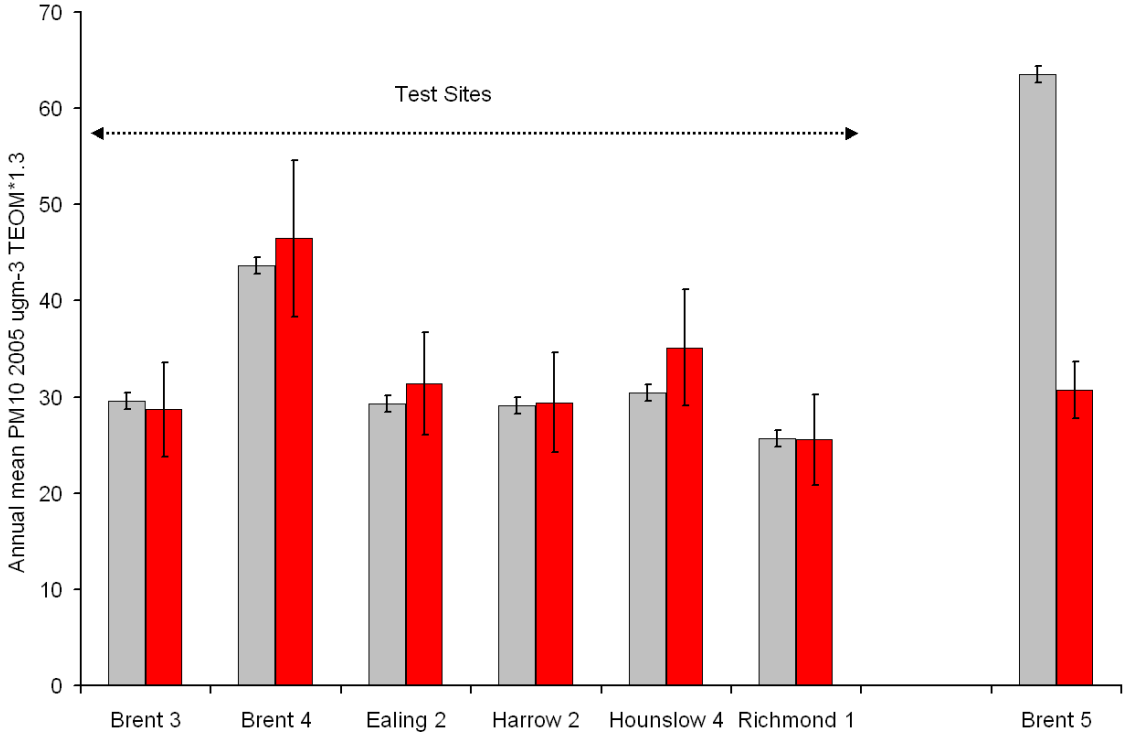

Figure 4 Measured and modelled 2005 annual mean PM_{10} concentrations at Brent 5 and the 6 roadside test sites. Uncertainty estimates are shown at 2 σ. Measured concentrations are shown grey and modelled concentrations are shown in red.

Source apportionment of mean PM_{10} concentration

Results of the source apportionment of the mean concentration of PM_{10} at Brent 5 are shown in Figure 5 and Table 4. PM_{10} from the local – other source made the largest contribution to the mean concentration at the site (33 +/- 3 µgm^{-3} TEOM *1.3 or 53%). All background sources accounted for 29 % and the TEOM offset accounted for a further 6%. The vast majority of the 65% of PM_{10} arising locally was from the local – other source which exceeded the local primary by a factor of greater than 4.

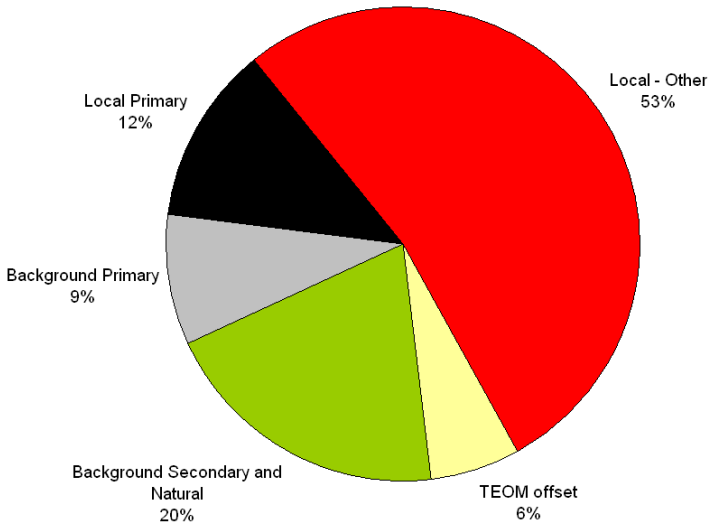

Figure 5 Source apportionment of mean PM_{10} concentration at Brent 5 - Mar 2004 to end 2005.

Source	Mean concentration μgm^{-3} TEOM *1.3 Mar 2004 – Dec 2005
TEOM offset	4
Background Secondary and Natural	13
Background Primary	6
Local Primary	8
Local - Other	34
Total	**65**

Table 4 Source apportionment of mean PM_{10} concentration at Brent 5 - Mar 2004 to end 2005.

The ratio of NO_X : primary PM_{10} emissions from the London Atmospheric Emissions Inventory were used to determine a worst case ratio as a sensitivity test. The worst case emitter was found to be a pre-Euro rigid HGV with NO_X : primary PM_{10} of 0.21 μgm^{-3} ppb^{-1} (including an estimate for non-exhaust emissions such as tyre and break wear) compared to 0.16 μgm^{-3} ppb^{-1} determined from the NO_X : primary PM_{10} concentration ratio at sites across London and SE England. Use of the worst case ratio in the model reduced the local – other PM_{10} to 49% of the total measured concentration, a change of 2.7 μgm^{-3} TEOM *1.3, within the uncertainty estimate of 3.0 μgm^{-3} TEOM *1.3. Local primary PM_{10} increased to 14%, background primary increased to 12% and PM_{10} from background secondary and natural sources reduced to 17%.

Source apportionment of daily mean PM_{10} concentration

The daily mean time series of source apportioned PM_{10} concentration at Brent 5 is shown in Figure 6. Source apportionment was possible on 631 days during the 671 days study period. Source apportionment was not possible on 40 days due to the absence of NO_X and / or PM_{10} measurements at these times.

It is evident from Figure 6 that the daily mean PM_{10} concentration measured at the site is not constant but varies from day to day.

The maximum daily mean PM_{10} concentration at the site was 205 μgm^{-3} TEOM*1.3. A total of 21 days had mean concentrations of over 150 μgm^{-3} TEOM*1.3. Daily mean PM_{10} at the site exceeded 50 μgm^{-3} TEOM*1.3 on 352 of the 631 days during the study period. If the local other source was removed from the site, daily mean PM_{10} concentrations would have exceeded 50 μgm^{-3} TEOM*1.3 on only 32 days. This suggests that 320 days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3 was due to the local – other source. Looking at 2005 only, source apportionment was possible on 346 days, the measured concentrations exceeded 50 μgm^{-3} TEOM*1.3 on 180 of these days. In the absence of the local – other source the measured concentration at the site would have exceeded 50 μgm^{-3} TEOM*1.3 on only 17 (8 – 32, 2σ) days. If the local –other source was not present the site would have achieved the EU Limit Value / AQS Objective in 2005.

Between March 2004 and the end of 2005, the 32 days with mean PM_{10} 50 μgm^{-3} TEOM*1.3 that would have occurred in the absence of the local – other source were due to a combination of sources. Episodes dominated by background secondary and natural PM_{10} affected the site during late summer and autumn 2004, spring 2005 and autumn 2005. Episodes dominated by primary PM_{10} affected the site during the winter periods when pollution dispersion is weakest; such episodes during November and December 2004 and 2005 can be clearly seen in Figure 6.

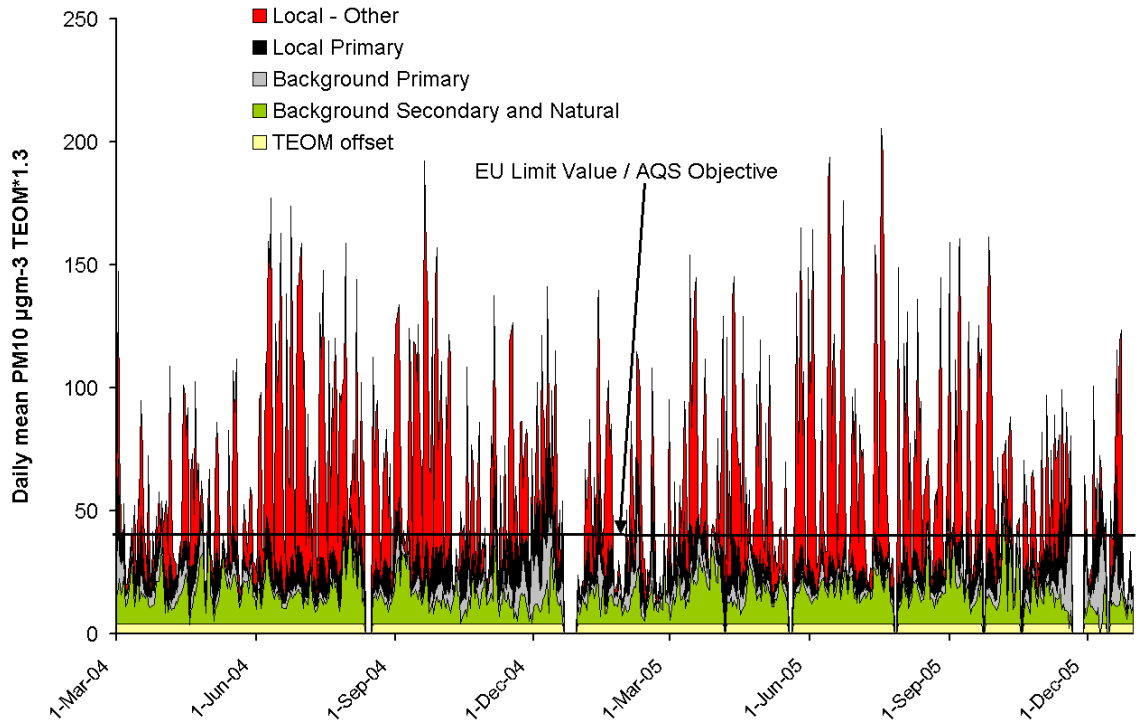

Figure 6 Time series of daily mean PM_{10} concentrations.

Quantification and characterisation of the local – other PM_{10} is a key objective of the study. Figure 7 shows the daily mean concentration of the local – other PM_{10} with uncertainty shown at 2σ. The maximum daily mean concentration of local – other PM_{10} during the study period was 171 +/- 4 μgm^{-3} TEOM*1.3. The local – other PM_{10} alone exceeded the EU Limit Value on 164 (151 – 188) days during the study period and on 80 (73 – 94) days during 2005. Figure 7 also shows evidence of a seasonal behaviour to the concentration of local – other PM_{10}, with higher concentrations evident during the summer months and lower concentrations during the winter months. The source apportionment model produced negative concentrations for the local – other PM_{10} on 26 days during the study period. However, the negative concentration on each of these days was within the expected model uncertainty and these apparent negative concentrations are therefore not significant.

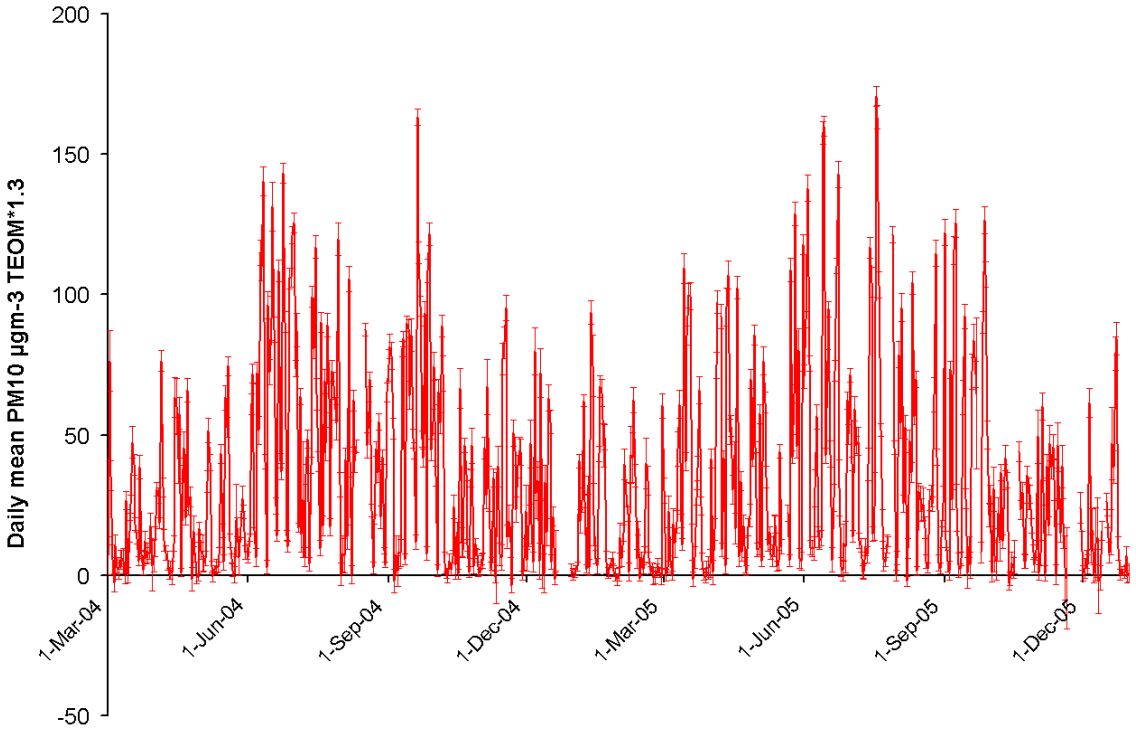

Figure 7 Time series of the modelled daily mean PM_{10} concentration from the local - other source. Uncertainty is shown at 2σ.

Source apportionment of PM_{10} concentration averaged by day of week and hour of day

Averaging pollution concentration by day of week and hour of day can lead to insight into the behaviour of the emissions sources affecting a monitoring site. Figure 8 shows the source apportioned concentration of PM_{10} at Brent 5 averaged by day of week and hour of day. Times are shown in GMT (with no correction for BST). Clear differences in the total mean PM_{10} concentration can be seen between weekdays and weekends with the total mean concentration being greater on weekdays than on Saturday and Sunday. From concentration minima during hour 2 GMT (hour 3 BST), mean PM_{10} concentrations rose rapidly during hour 5 GMT (hour 6 BST) each weekday morning and peaked around hour 14 GMT (hour 15 BST) before falling rapidly during hour 16 (hour 17 BST). A morning peak was also evident on Saturdays albeit a lower concentration compared with that experienced on weekdays. The total mean PM_{10} on Sundays showed comparatively little variation through the day. The mean concentration of the local – other PM_{10}, averaged by day of week and hour of day is shown in Figure 9.

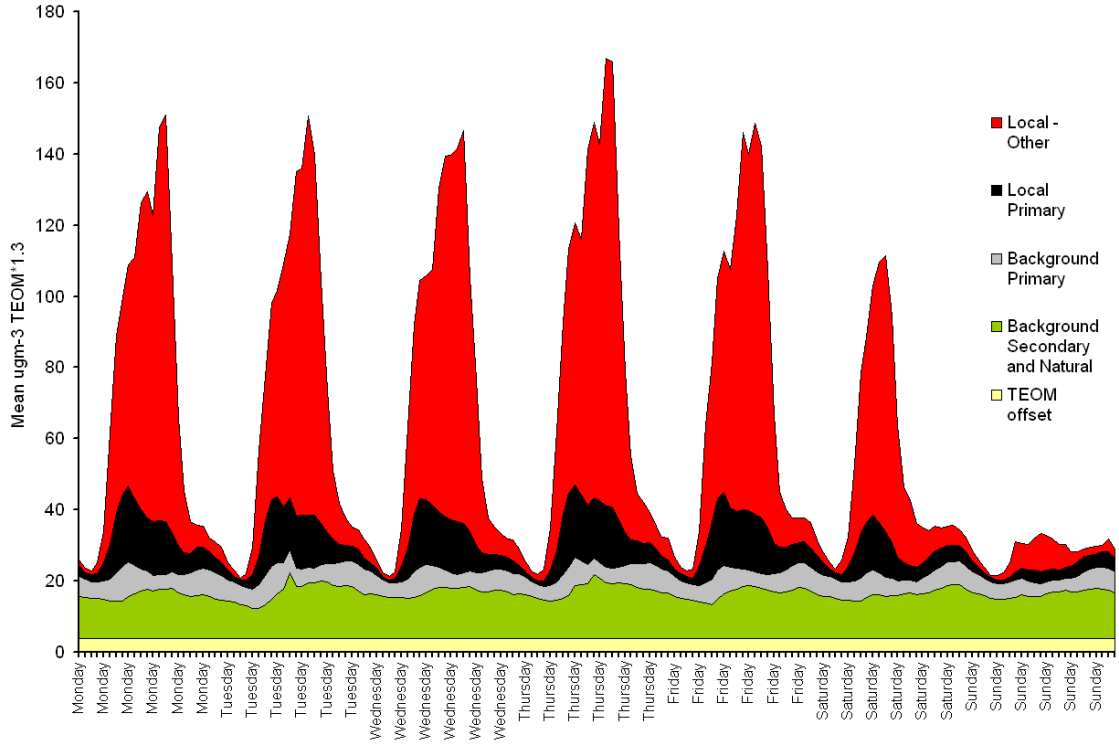

Figure 8 Source apportioned concentrations of PM_{10} at Brent 5 averaged by day of week and hour of day. Times were based on GMT.

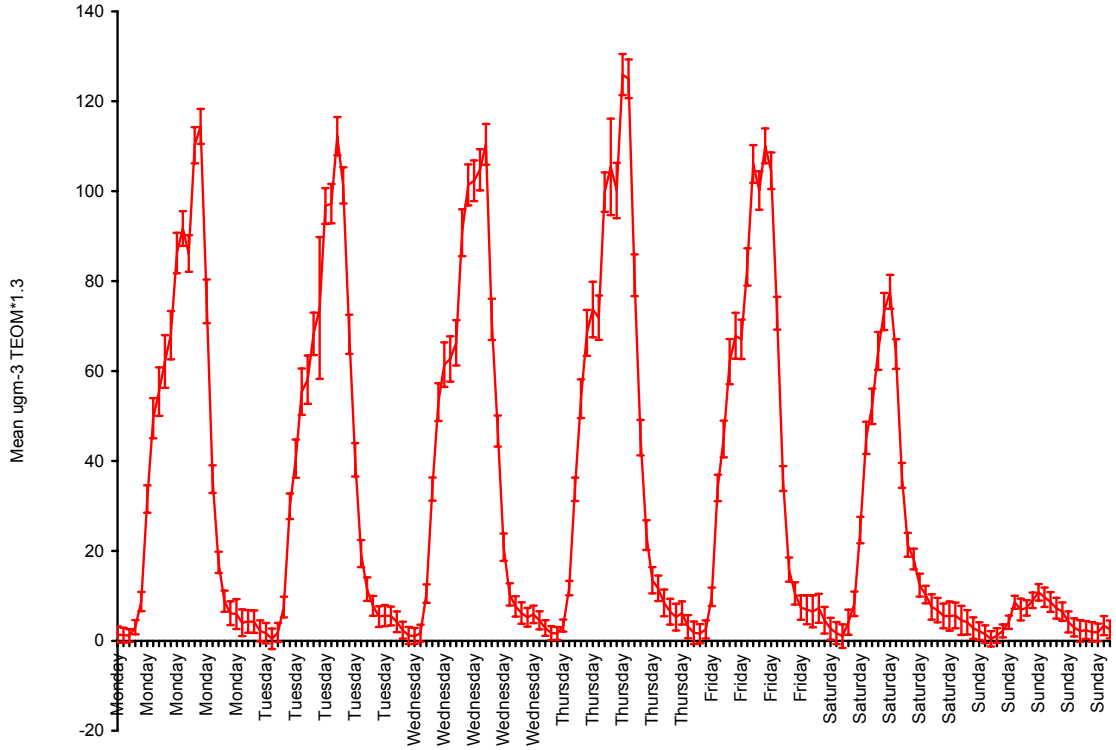

Figure 9 Concentrations of PM_{10} from local - other sources at Brent 5 averaged by day of week and hour of day. Times are shown in GMT and uncertainty estimates are shown at 2 σ.

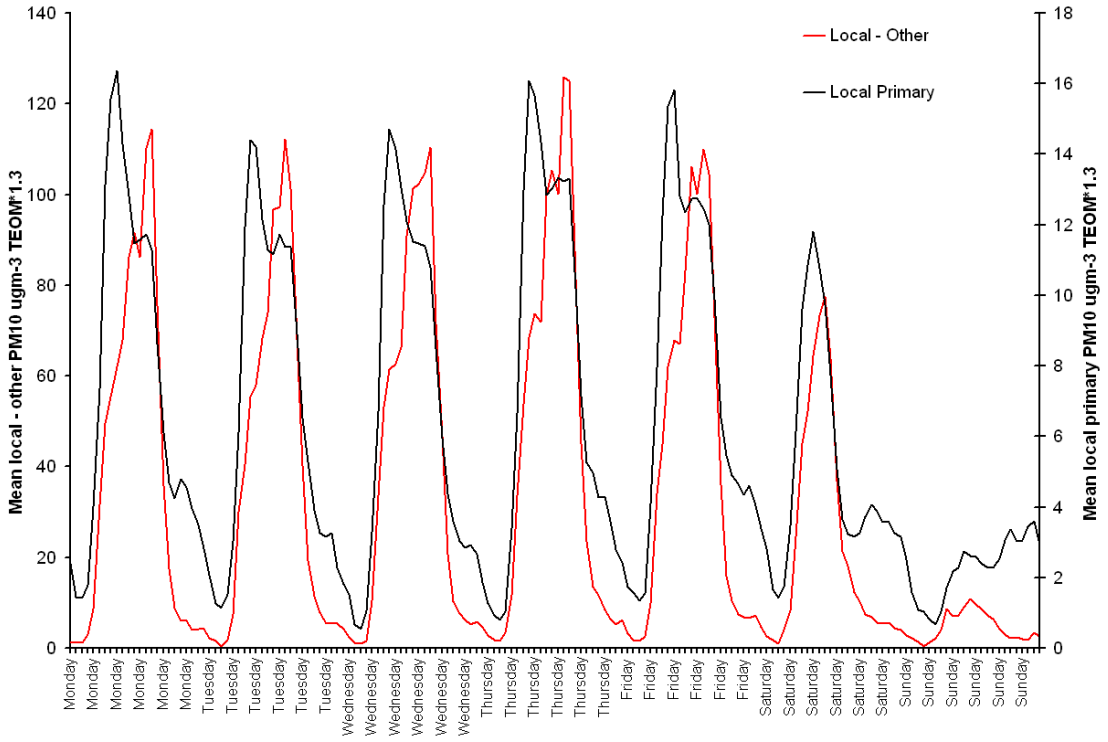

Figure 10 Concentrations of PM_{10} from local sources at Brent 5 averaged by day of week and hour of day. Times are shown in GMT. Local primary PM_{10} is shown on a secondary axis.

Figure 10 shows the mean concentration from the local sources with the local primary PM_{10} shown on a secondary axis. On initial inspection the variation in the concentration of PM_{10} from both local sources, primary and other, appear similar with the greatest concentrations measured on weekdays and Saturday mornings, and lower concentrations at night and on Sunday. However, Figure 10 also highlights some important differences between the weekday behaviour of the PM_{10} from the local primary and the local - other sources. The concentration of local primary PM_{10} peaks between 6h (7h BST) and 9h (10h BST) each working weekday in contrast to the local – other PM_{10}, which peaks during the early afternoon. Both local sources decline rapidly during the late afternoon. On Saturday and Sunday the afternoon elevation in local primary PM_{10} is not reflected in the local – other PM_{10} concentrations.

Mean PM_{10} by wind direction

Figure 11 shows the mean concentration of PM_{10} at Brent 5, averaged by wind direction. This analysis can provide important insight into the location of PM_{10} sources affecting a monitoring site.

The greatest overall mean concentration of PM_{10} arose during south westerly winds (240°). This elevation in mean concentration was caused by an elevation in the local – other and local primary PM_{10} from these wind directions. The concentration of PM_{10} from background secondary and natural sources was elevated during easterly winds (90°). This was indicative of long range transport of PM_{10} from continental sources as highlighted by APEG (1999) and Smith (1997). Easterly winds are also often linked to anticyclonic conditions and therefore periods of low wind speeds. Such conditions are not conducive to the dispersion of primary pollutants and therefore we would also expect elevated mean concentrations of PM_{10} from the background primary sources to be associated with easterly winds as also shown in Figure 11.

The lowest mean PM_{10} concentrations from background sources were measured at the site during westerly winds. Winds from a westerly direction usually have a maritime origin and do not contain large concentrations of secondary PM_{10}. Higher wind speeds are usually associated with westerly winds leading to greater dispersion of primary pollutants and therefore lower concentration of PM_{10} from background primary sources was experienced at this time.

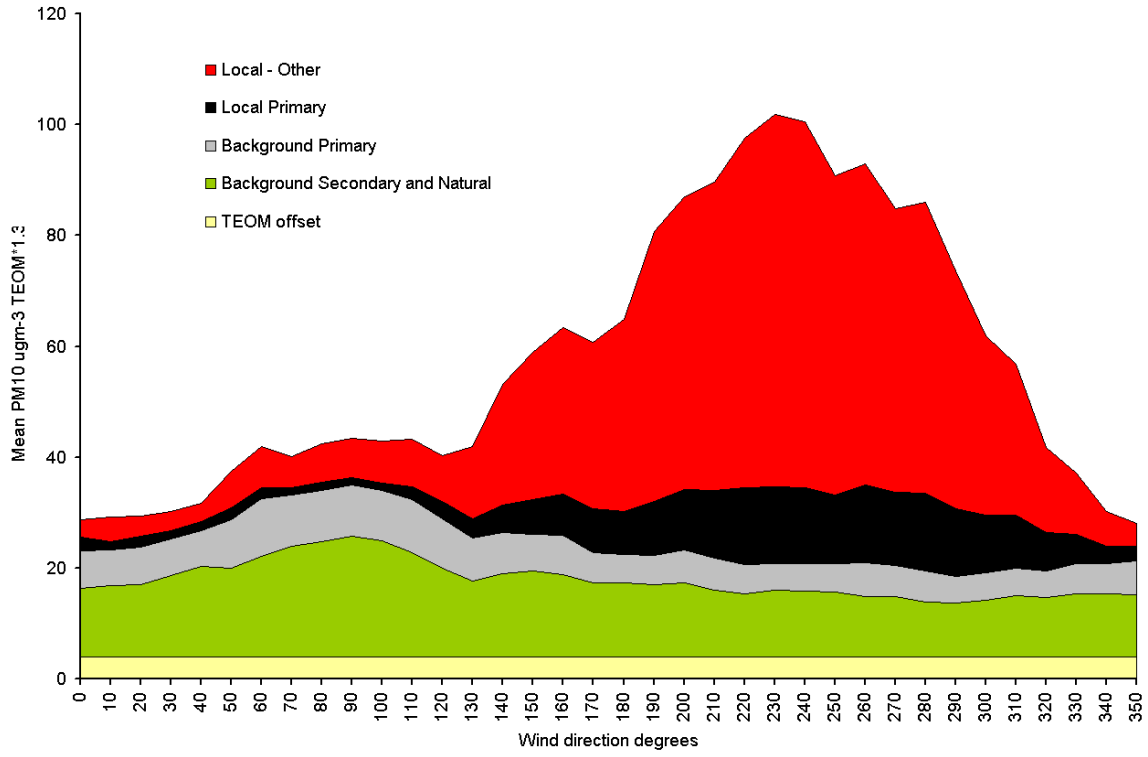

Figure 11 Source apportioned PM_{10} averaged by wind 10° direction sectors.

The contrasting background pollutant concentrations with respect to easterly and westerly winds is typical of sites in London (e.g. Fuller and Hedley 2006). However the behaviour of PM_{10} from local sources can be additionally affected by the location of local sources and buildings; the orientation of local roads with respect to wind direction and the geometry of street canyons are important determinants.

Figure 12 shows the mean concentration of local PM_{10} sources averaged by 10^{o} wind sectors. The mean concentration of the local-other PM_{10} was less than the uncertainty of the model for wind directions from 0^{o} and 20^{o} to 40^{o} sectors. Mean concentrations from all other directions were above the uncertainty estimate and therefore above the detection limit of the model.

Local – other PM_{10} exhibited greatest concentrations when wind originated from directions between 140^{o} and 310^{o}. This showed very good agreement with the orientation of Neasden Lane with respect to the monitoring site. These wind directions also agree well with the wind directions that would pass over Neasden Goods Yard from the northerly direction but emissions from the Goods Yard itself cannot explain the elevated concentrations observed from wind directions from the south. The greatest mean concentration of local – other PM_{10} concentration was measured when winds originated from 230^{o} to 240^{o}, the approximate direction of the entrance to Neasden Goods Yard. The mean concentration of local primary PM_{10} is less than the concentration of the local – other PM_{10} in all wind directions.

To further aid comparison between the local PM_{10} sources, Figure 13 shows the mean concentration of the local sources relative to the overall mean concentration for that source. Figure 13 shows the very good agreement between the sources of local primary and local – other PM_{10}. The local primary PM_{10} is determined from the local NO_X concentration and is therefore linked vehicle exhaust sources local to the site, vehicles using Neasden Lane and those within Neasden Goods Yard. The relatively low concentrations of local primary PM_{10} were from wind directions that did not involve airflow over or along Neasden Lane, support this attribution. There is no evidence of PM_{10} emissions from the railway.

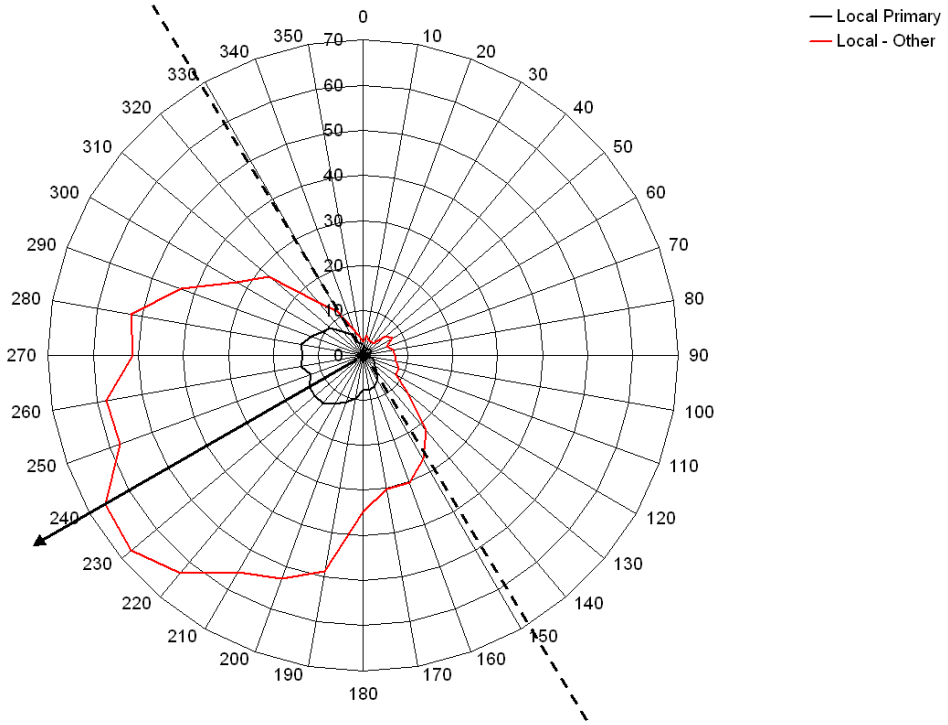

Figure 12 Source apportioned normalised mean concentrations of PM_{10} from local sources at Brent 5 averaged by 10^{o} wind sector. Local primary sources are shown in black, local - other sources are shown in red and the black dotted line denotes the approximate orientation of Neasden Lane and the arrow points in the approximate direction of the entrance to Neasden Lane Goods Yard. Mean concentrations are shown in μgm^{-3} TEOM*1.3.

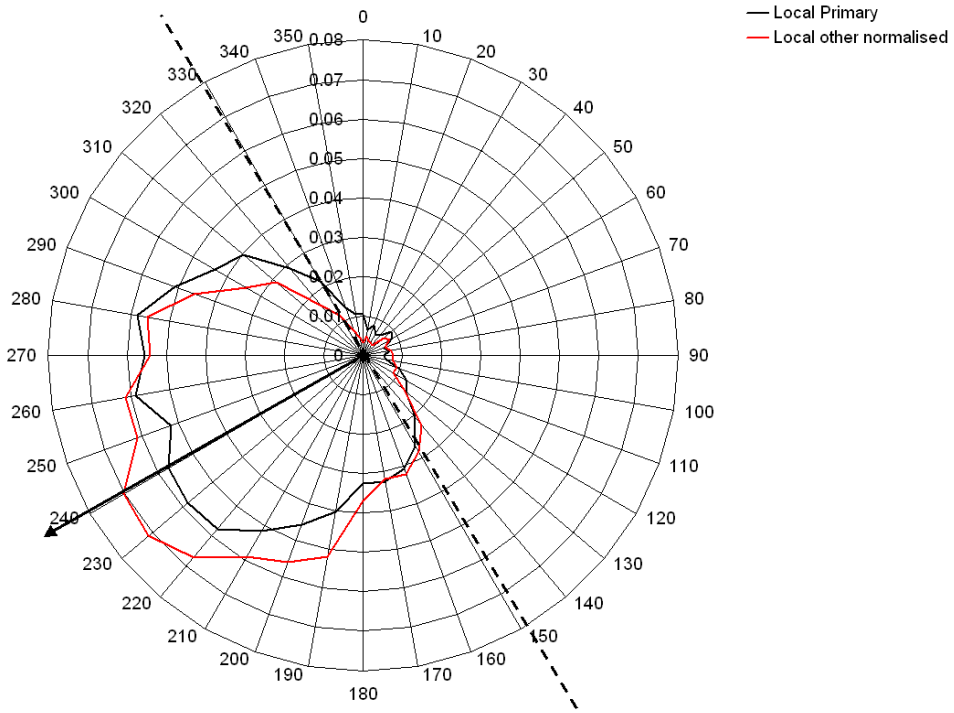

Figure 13 Source apportioned <u>normalised</u> mean concentrations of PM_{10} from local sources at Brent 5 averaged by 10° wind sector. Local primary sources are shown in black, local - other sources are shown in red and the black dotted line denotes the approximate orientation of Neasden Lane and the arrow points in the approximate direction of the entrance to Neasden Lane Goods Yard. Mean concentrations are relative to the overall mean concentration for that source.

Reductions in the concentration of Local – Other PM_{10} to achieve the AQS Objective

Source apportionment of daily mean concentrations allows the consideration of PM_{10} reduction scenarios. Two scenarios are considered here.

Firstly, the reduction in the concentration of the mean PM_{10} from local - other sources necessary to achieve the daily mean AQS objective. Figure 14 shows the annual number of days with mean concentration of PM_{10} above 50 μgm^{-3} TEOM*1.3 for various reductions in the mean concentration of local – other PM_{10} based on measurements made during 2005. Pro-rata allowance was made for days lost due to incomplete measurement data. The annual number of days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3 appears very insensitive to reductions in the concentration of the local – other PM_{10} of less than 30%. The majority of working weekdays at Brent 5 have PM_{10} concentrations considerably above 50 μgm^{-3} TEOM*1.3 (see Figure 6) and thus small reductions in the local – other PM_{10} concentration make little difference to the annual number of days with mean PM_{10} above this concentration. It is estimated that the mean concentration of local – other PM_{10} needed to be reduced by around 90% for the site to have met the AQS Objective during 2005.

Secondly, the reduction in the concentration of the annual mean PM_{10} from local - other sources necessary to achieve the daily mean AQS objective. Due to the statistical distribution of daily mean PM_{10} concentrations, the annual mean PM_{10} objective of 40 μgm^{-3} TEOM*1.3 is easier to achieve at most monitoring sites when compared to the daily mean objective. This is also the case at Brent 5. The annual mean AQS Objective could have been achieved in 2005 with a reduction of 70 +/- 4 %.

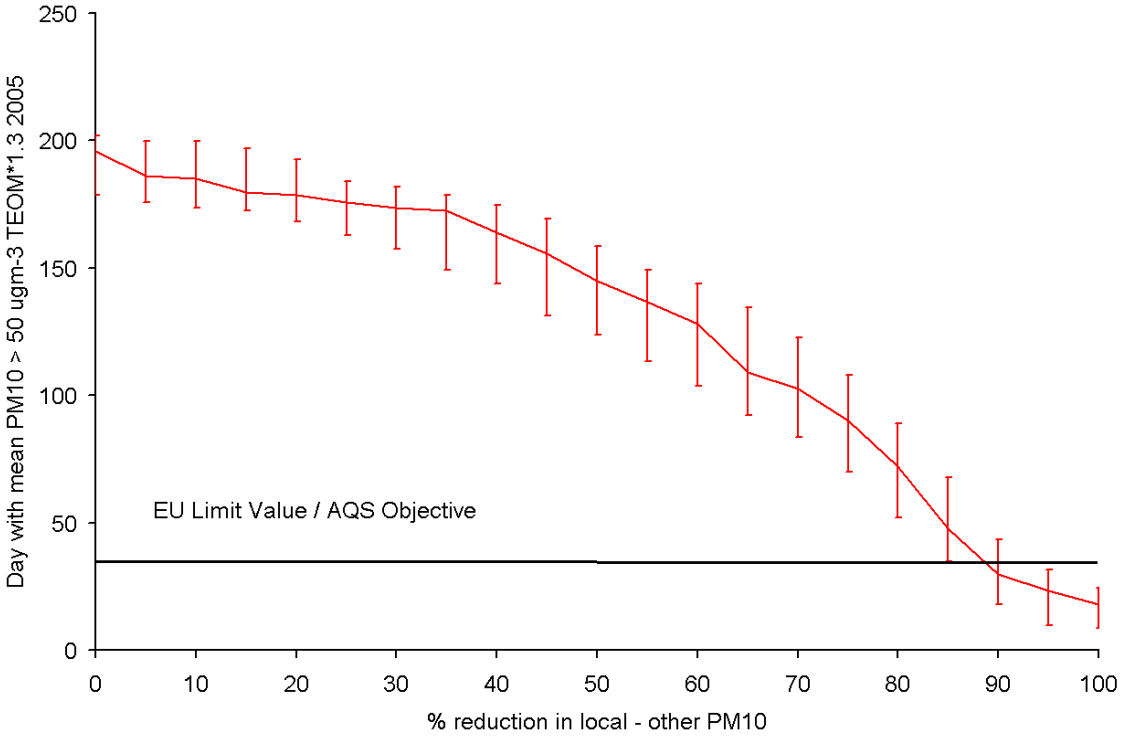

Figure 14 Reduction scenarios for the concentration of local - other PM_{10}, compared to the daily mean AQS Objective. Pro-rata adjustment was made for measurement availability.

7. Conclusions

During 2005 the Brent 5 monitoring site measured 180 days with mean PM_{10} concentration above 50 μgm^{-3} TEOM*1.3. This was greatly in excess of the EU Limit Value and AQS Objective of 35 days. It was the second highest monitoring site in London with respect to this measure of PM_{10} concentration. During 2005 the annual mean concentration at the site was 62 μgm^{-3} TEOM*1.3, breaching the EU Limit Value and AQS Objective of 40 μgm^{-3} TEOM*1.3.

Source apportionment of the measured PM_{10} concentration was required to understand the sources of PM_{10} at the site. The source apportionment model performed well. When compared with PM_{10} concentrations at 6 nearby roadside sites, the model showed good agreement and confirmed that the uncertainty estimates were realistic. However at Brent 5 the model did not agree with the measured concentrations indicating the presence of a further source of PM_{10} at the site. This source was termed local – other PM_{10}.

Source apportionment over the period 1st March 2004 to the end of 2005 showed that 53 (+/- 6, 2σ) % of the PM_{10} measured at the site came from local – other sources.

The mean concentration of PM_{10} at Brent 5 showed considerable day to day fluctuation reaching a peak daily mean concentration of over 200 μgm^{-3} TEOM*1.3. The vast majority of the days with mean PM_{10} concentration above 50 μgm^{-3} TEOM*1.3 were due to PM_{10} from the local – other source. If the local – other PM_{10} source was not present during 2005, the site would have experienced 17 (8 – 32, 2σ) days with mean PM_{10} above 50 μgm^{-3} TEOM*1.3 and therefore would have achieved the AQS Objective for the year.

The annual mean AQS Objective could have been achieved in 2005 with a reduction of 70 +/- 4 % in the mean concentration of local – other PM_{10}. The daily mean AQS Objective could have been met in 2005 with a reduction of around 90% in the mean concentration of local – other PM_{10}.

The local – other PM_{10} source dominated the measured PM_{10} concentrations at the site during working hours on weekdays and during Saturday mornings. It is likely that the local – other PM_{10} originates from a source that operates at these times.

Local – other PM_{10} exhibited greatest concentrations when wind originated from directions between 140^{o} and 310^{o}. This showed very good agreement with the orientation of Neasden Lane with respect to the monitoring site. The greatest mean concentration of local – other PM_{10} concentration was measured when winds originated from 230^{o} to 240^{o}, the approximate direction of the entrance to Neasden Goods Yard, although there was no clear evidence of a point source of PM_{10} within Neasden Lane Goods Yard itself. It should be noted that the entrance to the Goods Yard is shared with many operators.

Very good agreement was found between the sources of local primary and local – other PM_{10} with respect to wind direction. The local primary PM_{10} was determined from the local NO_X concentration and was therefore linked to vehicle sources local to the site; vehicles using Neasden Lane and those within Neasden Goods Yard. It is therefore likely that the local – other PM_{10} also originates from vehicle activity both within the yard and on Neasden Lane. Although, the local – other PM_{10} appears to originate from vehicle sources it cannot be accounted for by tailpipe emissions and expected mechanical tyre and break wear. It is therefore likely that the local – other PM_{10} originates from the resuspension of silt from the road surface or direct suspension of material from 'dusty' vehicles.

There were important differences between the information gained from the mean concentrations of the local PM_{10} sources with respect to wind direction when compared with local PM_{10} averaged by hour of day and day of week. The relative concentration of the local sources with respect to wind direction suggests that both the local primary and local – other PM_{10} came from the same source. However, the maximum concentration of the local sources did not occur at the same time each weekday. The local primary sources peaked during the morning rush hour whereas the local – other peaked at around lunchtime. A similar pattern was observed at Bexley 4, which is located close to a waste transfer facility at Manor Road, Erith (Fuller and Baker 2001).

Venkatruam (2000) highlighted the weaknesses of EPA AP 42 model and the complexities of estimating resuspension of dust from paved roads empirically by road silting, vehicle speed and vehicle weight. The situation at Brent 5 is also complex. From the measurements at Brent 5 it is possible to have considerable traffic PM_{10} emissions from Neasden Lane without corresponding emissions of local – other PM_{10}, during the early morning and at weekends for example. Possible explanations may include damp early morning conditions suppressing resuspension at these times or a requirement for fresh material to be deposited before resuspension can take place. Alternatively the relatively low resuspension during the morning traffic peak could be linked to slower vehicle speeds during the morning traffic peak or fewer heavy vehicles at this time. However it would be difficult to conclude that the source of local – other PM_{10} was not related to traffic activity.

Although no evidence of fugitive sources of local – other PM_{10} was detected at the Brent 5 site we cannot rule out fugitive sources affecting receptors outside the Neasden Goods Yard boundary. During 2006 the Environment Agency (EA) placed a PM_{10} and $PM_{2.5}$ monitoring site in the west part of Neasden Goods Yard, immediately to the west of the railway line (Shepard et al. 2006, Shutt 2007). The site operated for 113 days. PM_{10} concentrations exceeded 50 μgm^{-3} TEOM*1.3 on 63 days breaching the EU Limit Value and would be expected to exceed 50 μgm^{-3} TEOM*1.3 on 203 days in a full calendar year. Measurements from the EA site showed evidence of several sources of PM_{10} around the monitoring site, the largest PM_{10} source affecting the monitoring site originated on winds directions from south east of the Neasden Goods Yard. The sources of PM_{10} affecting the EA monitoring site were also active on weekdays and on Saturday mornings. The EA site measured both PM_{10} and $PM_{2.5}$ concentrations and provided valuable new information to show the local sources are dominated by particulate in the PM_{10} – $PM_{2.5}$ fraction. However NO_X concentrations were not measured at the EA site and it therefore not possible to determine if the PM_{10} sources were linked to transport activities in the Goods Yard or on Neasden Lane that dominated the local - other PM_{10} measured at Brent 5.

Although the Brent 5 monitoring site provides accurate measurements of the PM_{10} concentrations experienced opposite the entrance to Neasden Goods Yard, and close to nearby housing, it does not provide information about the area affected by these concentrations. In this respect, three important questions remain.

- What is the change in the emission rate of local – other PM_{10} along Neasden Lane and the haul route for vehicles leaving the Goods Yard? Source apportionment of PM_{10} at two other sites found lower concentrations at distances of between 450 to 1000 m from waste sites as shown in Table 5. Given that the local – other PM_{10} needed to be reduced to between 3 and 4 μgm^{-3} TEOM*1.3 to allow the Hammersmith and Fulham site to meet the AQS Objective it is likely that the area exceeding the Objective extends at least 500 to 1000 m along haul routes from Neasden Goods Yard.

Site	Distance from waste site along haul route	Mean local – other PM_{10} μgm^{-3} TEOM*1.3	Reference
H'smith & Fulham 3	450 m	5.7 (9.8 – 3.9, 2σ)	Fuller and Hedley 2006
Hastings	1000 m	10	Fuller and Hedley 2004

Table 5 Mean concentration of local - other PM_{10} at Hammersmith & Fulham 3 and at Hastings.

- What is the spatial area that breaches the AQS Objective? The area exceeding the AQS Objective will extend some distance from the centre line of Neasden Lane and the haul routes. This area should diminish with distance from the Goods Yard.

- To what extent do fugitive sources of PM_{10} within Neasden Lane Goods Yard affect the surrounding area and where are these sources located?

8. Recommendations

- The findings of this report should be incorporated into the Council's Air Quality Action Plan.

- The Council should work together with the Environment Agency and operators within Neasden Goods Yard to reduce the silt deposited on Neasden Lane. Determining the cause of the apparent seasonality in the concentration of local – other PM_{10} may assist this process.

- The Council should continue to monitor concentrations of NO_X and PM_{10} to assess the concentration reductions achieved by any abatement measures installed in Neasden Goods Yard. It should however be recognised that the day to day variation in the concentration of local – other PM_{10} and the apparent seasonality may confound this assessment in the short – term. This source apportionment study should be repeated annually to quantify changes in local – other PM_{10}.

- A further monitoring site should be installed further along Neasden Lane to determine the reduction of local – other PM_{10} with distance from the Goods Yard entrance. This would enable emission factors for the local – other PM_{10} to be determined and the area affected could be estimated using dispersion modelling.

- Further analysis of PM_{10} and $PM_{2.5}$ measurements from the EA monitoring site should be undertaken to account for background PM_{10} and $PM_{2.5}$ concentrations. Combining measurements from both the EA site and Bent 5 along with better information on the layout of activities within Neasden Goods Yard may enable the identification of specific fugitive sources.

- Further monitoring should be considered close to any residential areas on the boundary of the Goods Yard to determine the affect of any fugitive sources. Ideally this should include measurement of both PM_{10} (preferably by TEOM for consistency with measurements at Brent 5 and the EA site) and NO_X.

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