Characterization of the PM_{10} contribution from waste treatment industrial sources

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April 2012

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Title	Characterization of the PM_{10} contribution from waste treatment industrial sources

Customer	London Borough of Lewisham
Customer Ref	-

File Reference	ERG\AIRQUALI\LW3\Report
Report Number	-

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Table of Contents

List of figures and tables

Summary

This study characterizes the influence of the waste treatment industries on the PM_{10} concentration measured at the Air Quality Monitoring Site (AQMS) located in Mercury Way in the London Borough of Lewisham between 15th February 2010 and 20th September 2011. The contribution of the industrial source represented 27% of the mean PM_{10} daily concentration measured at the AQMS in Lewisham. Although the concentration measured met the EU Daily Limit Value, the industrial source increased the number of daily exceedances from 5 to 25 days compared to urban background AQMSs. When wind blew from the waste treatment sites it added on average 18.4 $\mu g \cdot m^{-3}$ to the PM_{10} urban background concentration. The daily and hourly pattern of the PM_{10} concentration in the AQMS was also described and compared to that found at a typical London background location.

1. Introduction

EU limit values and UK air quality objectives are in force for the control of ambient PM_{10} concentrations. Both EU and UK legislation requires ambient PM_{10} concentrations to be less than 40 $\mu g \cdot m^{-3}$ as an annual mean and the daily mean PM_{10} concentration should not exceed 50 $\mu g \cdot m^{-3}$ on more than 35 days per year. Perhaps surprisingly, the greatest concentrations of PM_{10} in London are not measured beside busy roads but in the vicinity of waste management sites (www.londonair.org.uk). This issue was first highlighted by PM_{10} source apportionment carried out in the London Borough of Bexley in 2000. Since this time several studies have been undertaken at various distances from a range of waste sites in London and the south east. These show that waste sites can contribute up to 30 $\mu g \cdot m^{-3}$ to annual mean PM_{10} alongside public roads up to 50 m from the entrance to waste management sites. The resuspension of track out PM_{10} and direct suspension of PM_{10} from vehicles has been shown to contribute to local PM_{10} concentrations at a distance of around 1 km from the waste site entrance. Additionally concern has been raised about the potential toxicity of PM from waste sites (Fuller and Baker, 2008; Godri et al. 2010).

Recognising these issues, the assessment of PM_{10} from waste sites has been included in local air quality management (DEFRA, 2009). This requires detailed assessment of PM_{10} from a waste site if there is relevant exposure, a history of nuisance complaints or visible dust around the site. Such concerns were raised with respect to several blocks of flats on Mercury Way, in the London Borough of Lewisham, which are in close proximity to a group of waste businesses.

A monitoring site was installed in February 2010 to assess the impacts of these waste businesses on PM_{10} concentrations. The monitoring site was connected to the London Air Quality Network run by King's College London for the boroughs. King's were also contracted to write a short report analysing local PM_{10} sources following the first year of measurement. Analysis was originally scheduled for spring 2011 however poor data capture during summer 2010 meant that the analysis was delayed to obtain measurements representative of the full range of seasonal conditions.

2. Site descriptions and measurement methods

The Air Quality Monitoring Site (AQMS) at Lewisham – Mercury Way (LW3) is an Industrial site located in the London borough of Lewisham (51.48°N, 0.05°E). A waste treatment industrial complex (with scrap metal and iron; waste separation; and asphalt treatment and processing businesses) is located between the north-north-west (NNW) and the north-east (NE) of the AQMS. The waste treatment industrial complex comprises different enterprises. The closest is located around 35 m NE of the AQMS and the perimeter of furthest is around 50 m NNW of the site, though the main activity takes place up to 100m from the AQS. A mainline railway line is located round 70 m east of the AQMS. A residential area is located west of the AQMS (Figure 1).

Figure 1. Map showing the location of the AQMS Redbridge 1 (RB1; urban background), Redbridge 3 (kerbside site), Redbridge 4 (roadside site) and Lewisham 3 (industrial site). A closer zoom of LW3 is shown in the bottom-right part of the map. Source: maps.google.com.

The site was equipped with a Beta Attenuation Mass Monitor (BAM) which measures particulate PM_{10}. In this device, a Beta source is coupled to a sensitive detector which counts the Beta particles. As the mass of PM_{10} particles sampled increases the Beta count is reduced. The relationship between the decrease in count and the PM_{10} mass is computed according to the Beer-Lambert law (DEFRA, 2010). Hourly measurements are collected and stored in a SQL database at King's College

London. Data was validated manually every 1-3 days, and converted into PM_{10} equivalent measurements and ratified retrospectively.

Redbridge – Perth Close (RB1; 51.57°N, 0.08°E) is an urban background site located ~15 km north-east of LW3. Like LW3, the RB1 AQMS is equipped with a BAM analyser to monitor PM_{10} particulates. Data from two other sites, Redbridge – Fullwell Cross (RB3; 51.59°N, 0.08°E) and Redbridge – Gardener Close (RB4; 51.58°N, 0.03°E) (a kerbside and roadside site, respectively), were also used in this study (see Figure 1). All sites were equipped with BAM analysers to measure PM_{10} particulate concentrations. Data were stored, validated and ratified using the same protocols.

The meteorological data used in this report, mainly wind direction and wind speed, has been compiled from several meteorological stations across London belonging to the London Air Quality Network. Although this data does not represent the very local meteorological conditions at each AQMS, it offers a good quality data set representative of the synoptic weather conditions in London.

3. Results

3.1 Annual statistics

Table 1 summarises the descriptive statistics for the PM_{10} concentrations measured at RB1, LW3, RB3 and RB4 from 15th February to 20th September 2011. The kerbside and roadside sites (RB3 and RB4) measured greater mean hourly concentrations (29.3 and 27.8 $\mu g \cdot m^{-3}$, respectively) than the industrial site LW3 (23.8 $\mu g \cdot m^{-3}$). Hourly peak concentrations over 100 $\mu g \cdot m^{-3}$ were more frequent at LW3 (112 times) compared to RB3 (29 times) and RB4 (16 times).

Table 1. Descriptive statistics for the PM_{10} concentration (expressed in $\mu g \cdot m^{-3}$) measured from 15th February 2010 to 20th September 2011 at RB1, LW3, RB3 and RB4.

	RB1	LW3	RB3	RB4
Mean ± 1σ	15.5 ± 11.6	23.8 ± 19.9	29.3 ± 14.2	27.8 ± 14.7
1st quartile	8.2	12.0	20.1	18.3
Median	12.8	18.0	26.9	25.4
3rd quartile	18.8	28.4	35.2	34.3
Minimum hourly	-2.9	-3.6	-8.2	-1.8
Maximum hourly	215.2	302.2	251.7	233.5
No. days daily mean > 50 $\mu g \cdot m^{-3}$ *	5 (5)	25 (21)	31 (24)	19 (12)

***In brackets, using data from 1st September 2010 and 31st August 2011**

Daily mean concentrations at LW3 and RB1 are shown in Figure 2. The EU PM_{10} daily Limit Value (50 $\mu g \cdot m^{-3}$) is also marked as a reference value. Between the 1st September 2010 and 31st August 2011 the EU Daily Limit value threshold was exceeded on 5 days at RB1 and 21 days at LW3 (25 days when considering the entire data set). The number of exceedances at LW3 was similar to that at the kerbside site RB3 (24 days). Overall, the concentration measured at LW3 achieved the EU Limit Values with no more than 35 days per year exceeding 50 $\mu g \cdot m^{-3}$ as daily mean $PM_{10;}$ and the annual mean did not exceed 40 $\mu g \cdot m^{-3}$.

As observed in Figure 2, on most days when LW3 exceeded the EU Daily Limit Value, the urban background concentration was already high (i.e. April 2010 and 2011; 7th November 2010; 13th and 27th July 2011) and the local source added to the already elevated regional-scale concentration. There were other periods when the concentration measured at LW3 was high (>50 $\mu g \cdot m^{-3}$) while the urban background concentration remained low (~20 $\mu g \cdot m^{-3}$; i.e. February and March 2010; May 2010). Only 2 days during these periods (LW3 minus the RB1 concentration) exceeded the 50 $\mu g \cdot m^{-3}$ daily mean threshold itself.

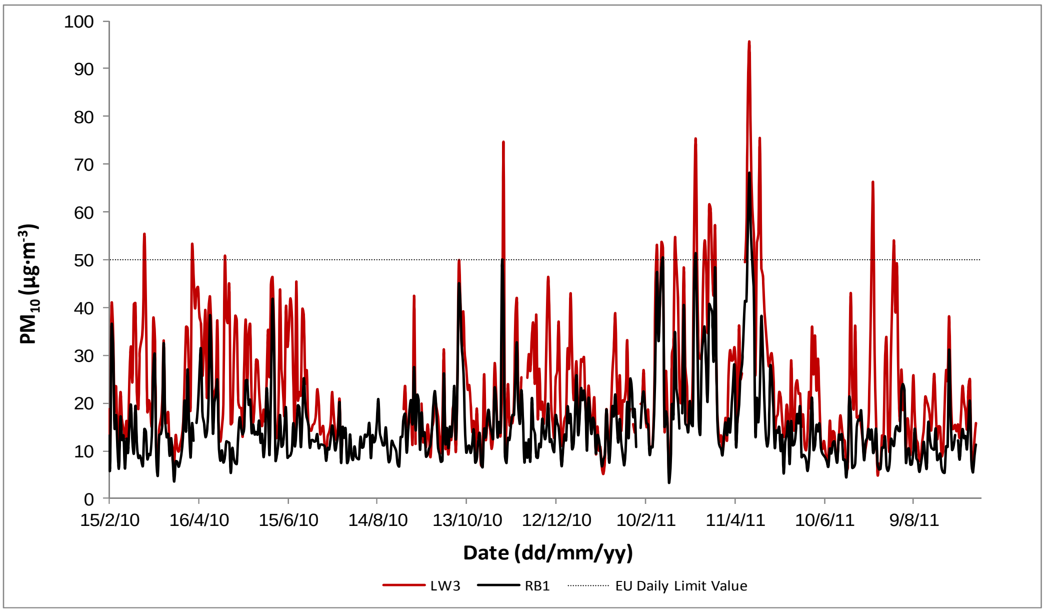

Figure 2. Daily mean concentration at LW3 and RB from the 15th February 2010 and 20th February 2011. The EU PM_{10} Daily Limit Value threshold (50 $\mu g \cdot m^{-3}$) is also shown (dotted black line).

Figure 3 represents the percentage of background to local PM_{10} for the daily mean concentration measured at LW3. On average, the background level represented 72.6% of the daily mean concentration at LW3 while the local source contributed 27.4%. As observed in Figure 3, there were a few days when the 24 hour mean PM_{10} concentration measured at RB1 is higher than the measured at LW3 (identified by negative local source contribution in Figure 3). They represented only 11.5% of days for the entire data set here presented so the PM_{10} concentration measured at RB1 could be used as an urban background concentration for the majority of days from the period considered.

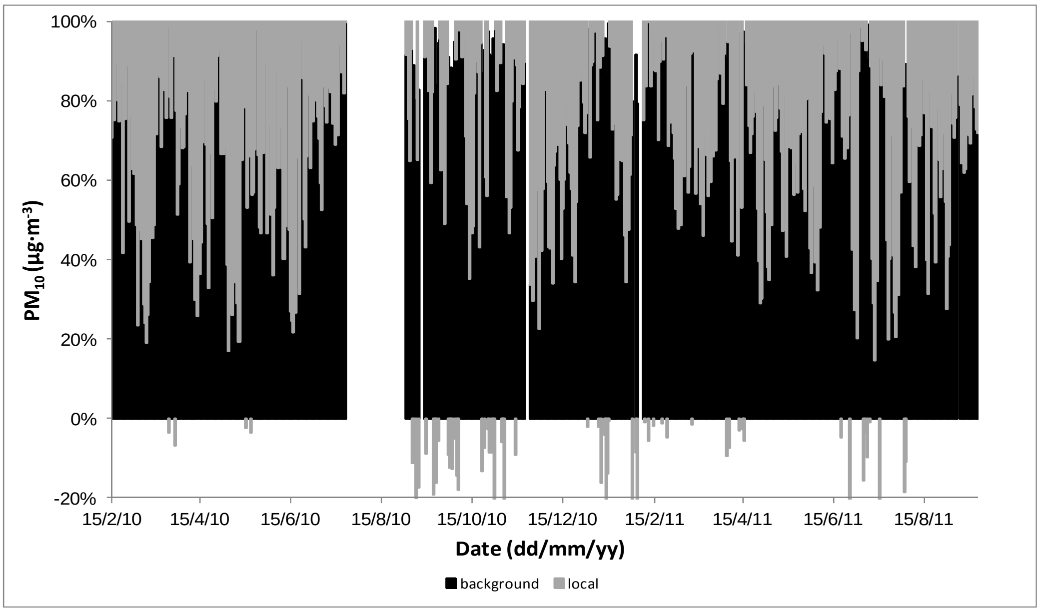

Figure 3. Percentage of background and local contribution of the mean daily concentration measured at LW3.

3.2 PM_{10} sources at Lewisham 3

The potential local sources of pollution were explored through bi-variate polar plots that show the mean concentration measured at one site against wind direction and wind speed. This type of plot has been used to identify and locate potential local sources of NO_x at monitoring sites in the vicinity of airports (Carslaw et al., 2006); and traffic-related pollutants in a street canyon in central London (Tomlin et al., 2009).

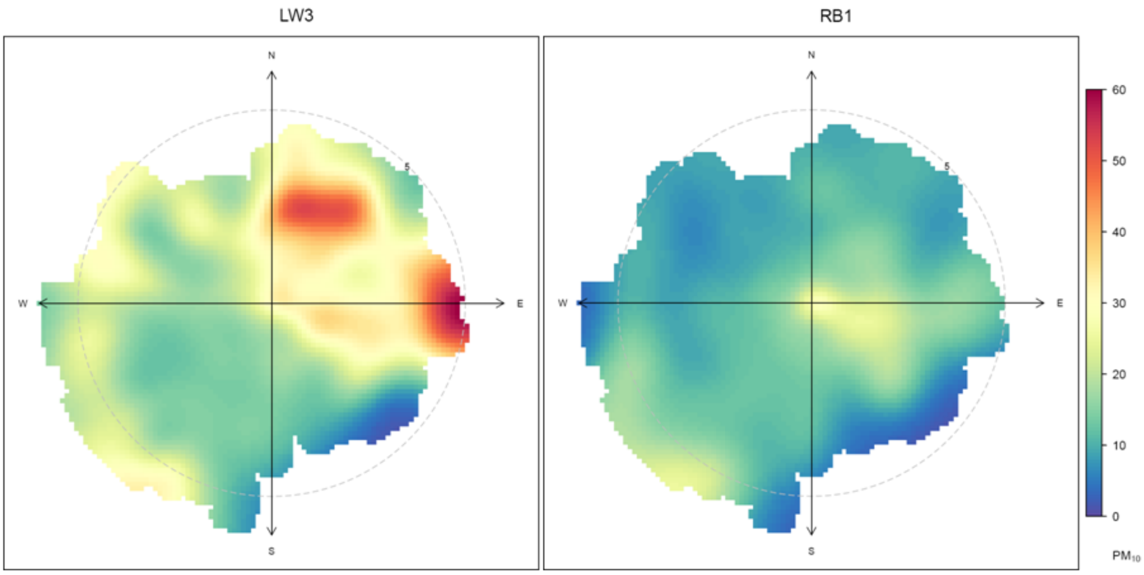

Figure 4. Bivariate polar plots for PM_{10} (µg·m^{-3}) at Lewisham 3 (LW3-left) and Redbridge 1 (RB1-right). In each plot the wind speed increases radially outwards towards the circumference to 5 m· s^{-1}.

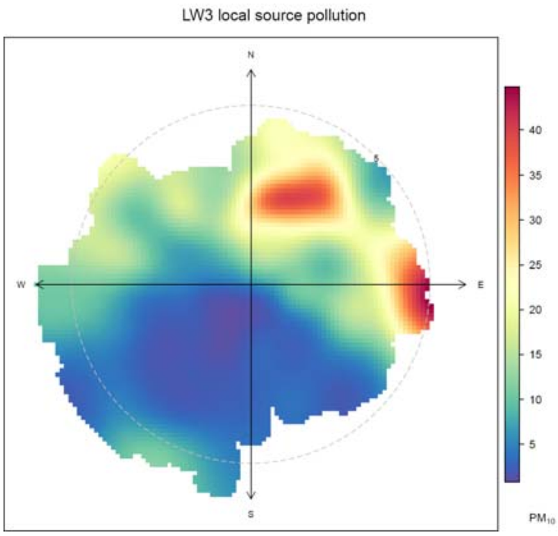

Figure 5. Bivariate polar plots for the PM_{10} ($\mu g \cdot m^{-3}$) local sources at Lewisham 3.

The bi-variate polar plots for hourly PM_{10} measurements from the 15th February 2010 to 20th September 2011 at both LW3 and RB1 are shown in Figure 4. High concentrations (~30 $\mu g \cdot m^{-3}$) were measured at RB1 at low wind speeds associated with stagnant weather conditions with no dispersion; from the SE sector at moderate wind speeds (~3$m \cdot s^{-1}$); and from the SW sector at high wind speeds (~6 $m \cdot s^{-1}$). The highest concentrations measured at LW3 were associated with north-easterly (NE) and easterly (E) winds. In order to study closely the local sources contributing the PM_{10} concentration measured at LW3, the urban background PM_{10} concentration measured at RB1 was removed from the LW3 concentration. This concentration was termed LW3 local. The bi-variate polar plot for the local PM_{10} sources at LW3 is represented in Figure 5. The concentration measured when the wind was blowing from the NE and E sectors was 45 $\mu g \cdot m^{-3}$ higher than the urban background concentration (Figure 5). The NE source was consistent with the waste treatment processes closest to the AQMS. Any PM_{10} from the waste treatment processes to the NNW of the AQMS may be more difficult to distinguish due to the larger distance between the NNW source and the AQMS. The E source was associated with easterly winds with wind speeds higher than 1.5 $m \cdot s^{-1}$ in the spring season in both 2010 and 2011 (see Figure 6).

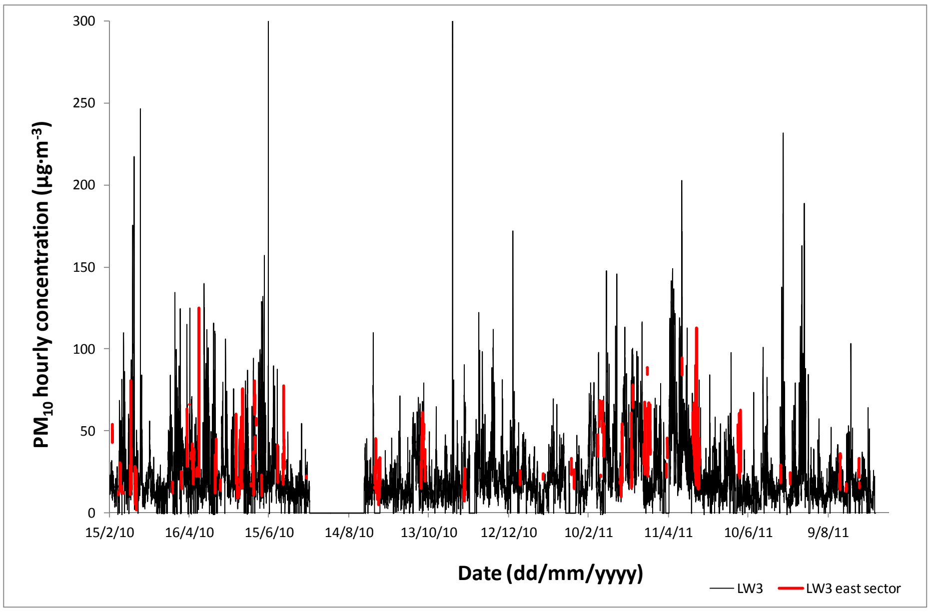

Figure 6. PM_{10} hourly data measured at LW3 (black). The red line denotes measurements done on easterly conditions (wind direction between 75 and 110 degrees north) and wind speed higher than 1.5 $m \cdot s^{-1}$

The seasonality of the local PM_{10} sources at LW3 is explored in Figure 7. The NE source was present all year long although the intensity of the source is greater in spring and summer. The E source was only present in spring as shown below.

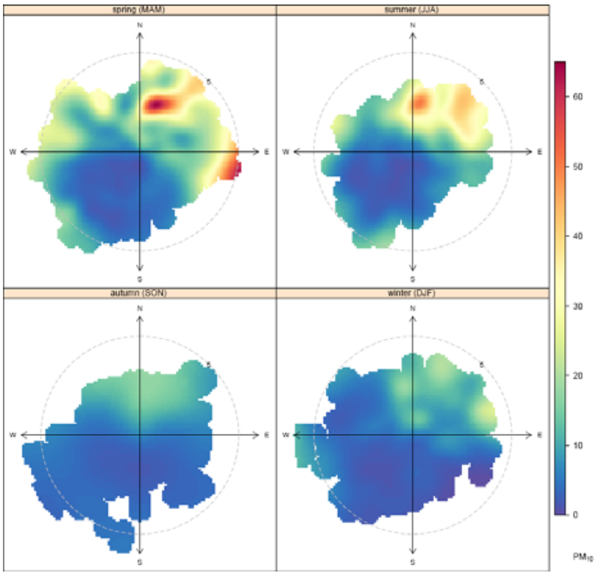

Figure 7. Bivariate polar plot for the local hourly PM_{10} measurements ($\mu g \cdot m^{-3}$) at Lewisham 3 split by seasons. MAM: March, April and May. JJA: June, July and August. SON: September, October and November. DJF: December, January and February.

Splitting the local source bi-variate plots by hour only the NE source was identified at LW3. Between 8 am and 6 pm (local time), the mean PM_{10} concentrations was 65 $\mu g \cdot m^{-3}$ above the urban background level as observed in Figure 8.

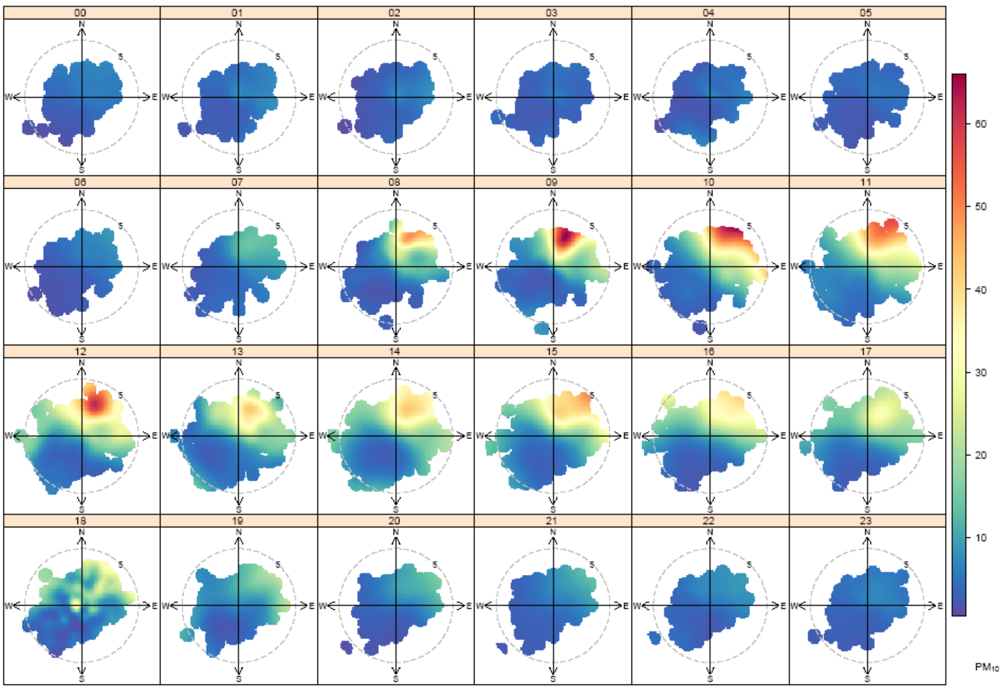

Figure 8. Bivariate polar plots for PM_{10} ($\mu g \cdot m^{-3}$) from local sources at Lewisham 3 split by hour of day.

The seasonality of the east source (seen in Figure 7) and the lack of a diurnal pattern (Figure 8) probably exclude any relationship with railway maintenance that takes place mostly at nights and weekends.

By considering only the hourly measurements for only those days when the 50 $\mu g{\cdot}m^{-3}$ daily mean threshold value was exceeded at LW3, PM_{10} two clear sources of PM_{10} (Figure 9, left): the SE and the N-NE sector were found. Removing the background concentration (Figure 9, right), only the N-NE source appears to be a relevant source of PM_{10} at LW3 for the days with exceedances. Easterly winds with wind speeds greater than 3 $m{\cdot}s^{-1}$ were not identified as a significant source of PM_{10} for the days with exceedances as observed in both graphs in Figure 9.

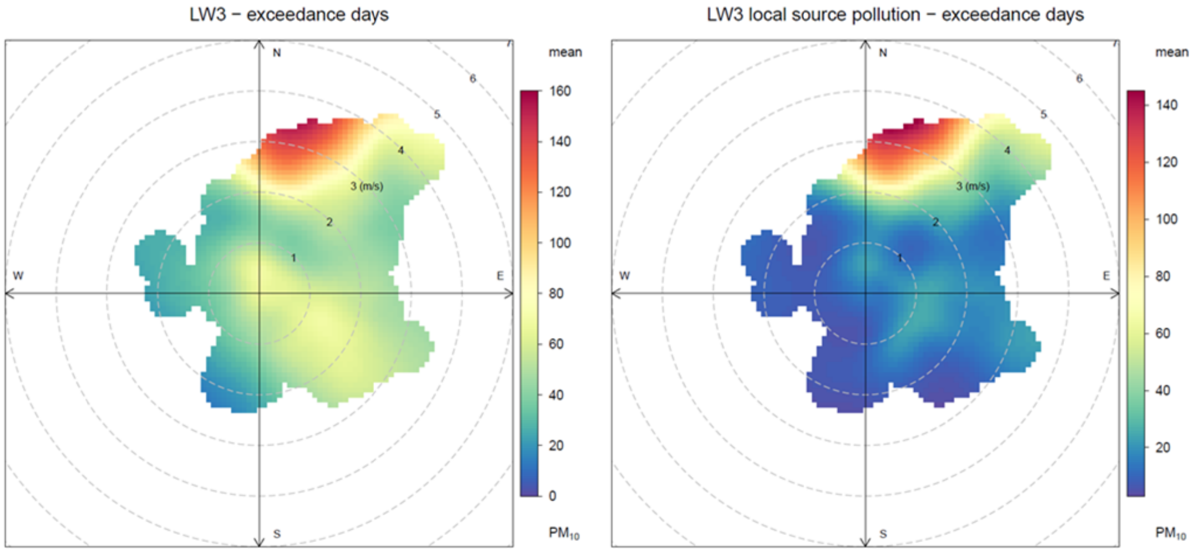

Figure 9. Bivariate polar plot for the hourly PM_{10} measurements (left) and bivariate polar plot for the hourly local PM_{10} measurements (right), expressed in $\mu g{\cdot}m^{-3}$, at Lewisham 3, for the days when the daily mean concentration was greater than 50 $\mu g{\cdot}m^{-3}$.

3.3. Time variation of PM_{10} sources at Lewisham 3

An in-depth view of the mean daily, weekly and seasonal variation of the PM_{10} concentration at LW3, RB1 and LW3 local is given in Figure 10. The mean PM_{10} at the urban background site (RB1) showed two peak concentrations from Monday to Friday, at 8 am and 9 pm (local time), associated with the morning rush hour and domestic heating, respectively. The temporal variation of PM_{10} concentration at LW3 shows mean PM_{10} concentrations 25 $\mu g{\cdot}m^{-3}$ were higher than urban background levels from 7 am to 6 pm. This pattern was repeated from Monday to Friday. On Saturday LW3 PM_{10} concentrations were higher than background between 7 am and 6 pm but the intensity of the local contribution barely contributed more than 10 $\mu g{\cdot}m^{-3}$ through the day. On Sundays the concentration at LW3 remained quite stable, slightly above the urban background concentration, ranging from 2.0 to 7.1 $\mu g{\cdot}m^{-3}$. On average, the PM_{10} concentration measured at LW3 was 10 $\mu g{\cdot}m^{-3}$ higher than the urban background concentration from Monday to Friday. At weekends, PM_{10} concentrations at LW3 were higher than the background concentration by only ~5-4 µg·m^{-3}.

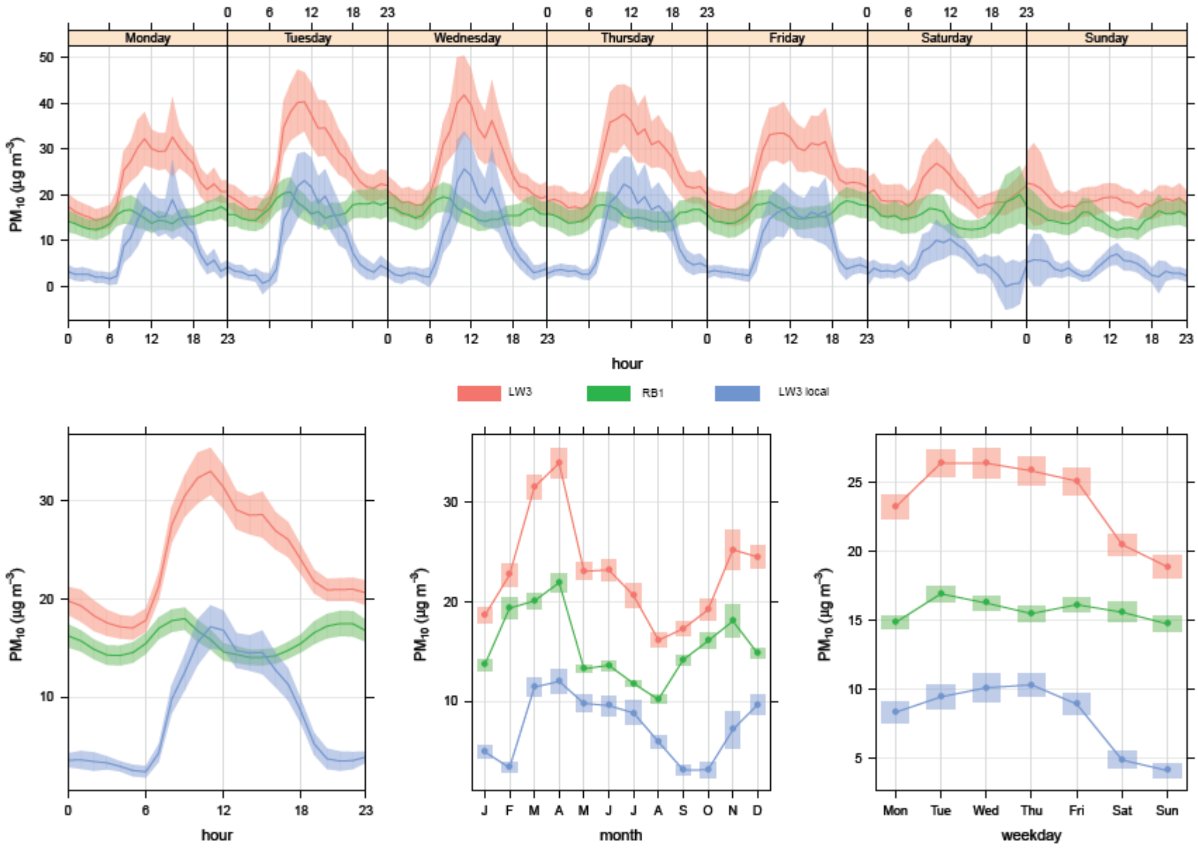

Figure 10. Hourly cycle at each day of the week (top); diurnal (bottom-left), seasonal (bottom-middle) and weekly cycles (bottom-right) of the PM10 concentration (expressed in µg·m^{-3}) measured at Lewisham 3 (LW3), Redbridge 1 (RB1) and for the local source at LW3 (LW3 local).

Figure 11 represents the mean daily, weekly and seasonal variation of the local PM_{10} concentration measured at LW3 when the wind was blowing from the direction of the waste industries (centred on NE but covering 330-80 degrees) and elsewhere. The descriptive statistics are summarised in Table 2. The mean PM_{10} measured at LW3 exceeded the urban background concentration by 60 µg·m^{-3} during working hours (7 am to 6 pm) Monday to Friday when the wind blew from the NE sector. The local contribution decreased on Saturday, when the concentrations did not exceed 30 µg·m^{-3}. The concentration at LW3 was 5.5 µg·m^{-3} above the urban background on Sundays for the NE sector as for the other wind sectors. Seasonally (bottom-middle plot on Figure 10), the NE local source increased from March to July, with a peak of activity in July. Overall, the NE local source at LW3 contributed in 18.4 µg·m^{-3} on top of the PM_{10} urban background concentration (Table 2) while the site only measured on average 4.8 µg·m^{-3} above the background level for the other wind sectors.

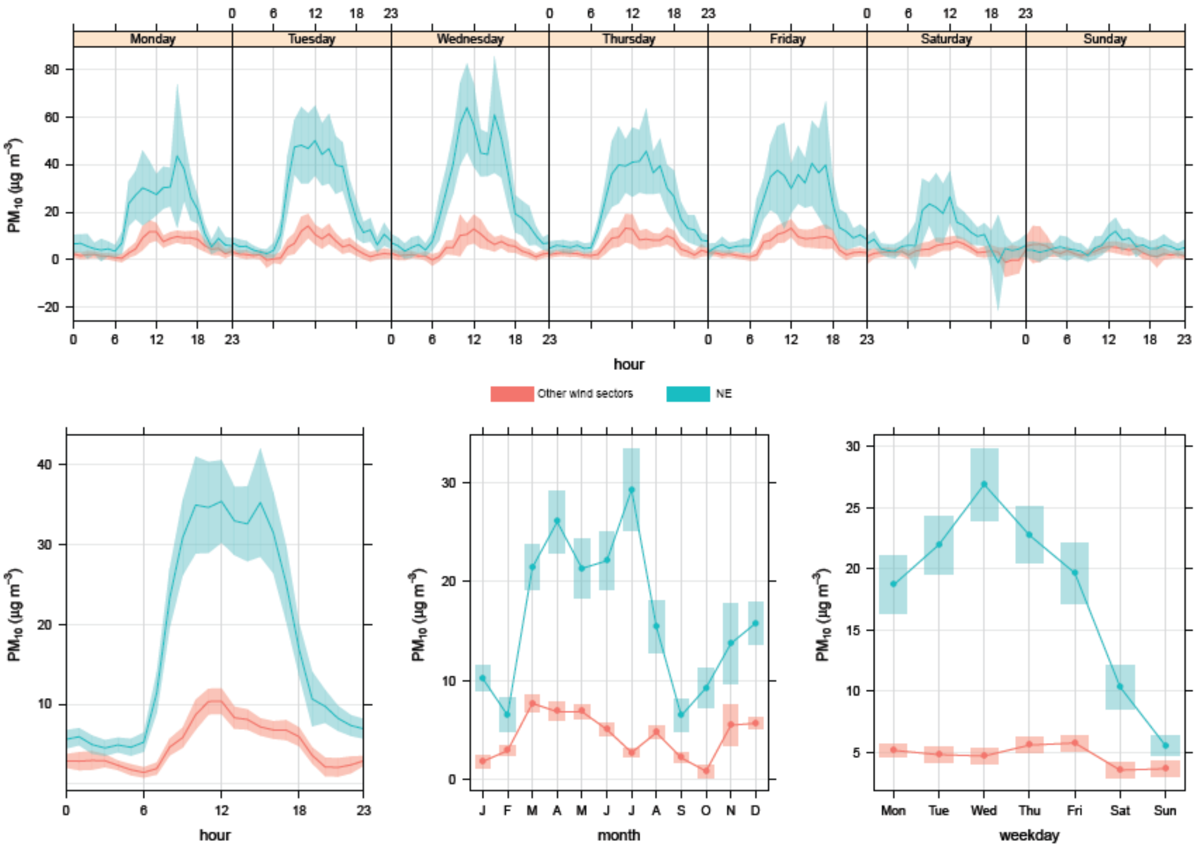

Figure 11. Hourly cycle at each day of the week (top); diurnal (bottom-left), seasonal (bottom-middle) and weekly cycles (bottom-right) of the local PM_{10} concentration (expressed in $\mu g \cdot m^{-3}$) measured at Lewisham 3 when the wind was blowing from the NE sector and from other wind sectors.

Table 2.Descriptive statistics for the local PM_{10} concentration (expressed in $\mu g \cdot m^{-3}$) measured from 15th February 2010 to 20th September 2011 at LW3 when the wind is blowing from the north sector (330-80 degrees) and elsewhere.

	LW3 local north	LW3 local elsewhere
Mean	18.4	4.8
1st quartile	4.0	-0.6
Median	10.0	2.8
3rd quartile	24.4	7.5
Maximum hourly	289.8	215.6

4. Conclusions and future

The local waste treatment industries were responsible for 27% of the mean PM_{10} at the AQMS in LW3. The local source raised the number of days exceeding the EU Daily Limit Value from 5 to 25 days compared to the urban background AQMS at RB1. When wind blew from the industrial sources the mean PM_{10} concentrations was on average 18.4 $\mu g \cdot m^{-3}$ above the urban background concentration. This contribution was slightly larger than the one from road-traffic sources as measured at RB3 (13.7 $\mu g \cdot m^{-3}$) and at RB4 (13.2 $\mu g \cdot m^{-3}$). The industrial sources had a marked weekly and daily pattern, with elevated levels from 7 am to 6 pm from Monday to Friday.

Chemical analysis of particles collected on the BAM tapes would improve our understanding of the processes and scales of influence (local *vs* regional) of the PM_{10} concentrations measured in the AQMS. Better assessment and categorization of the industrial and traffic related sources at this type of industrial sites could be also achieved by equipping the AQMS with traffic-related gases analysers such as NO_x.

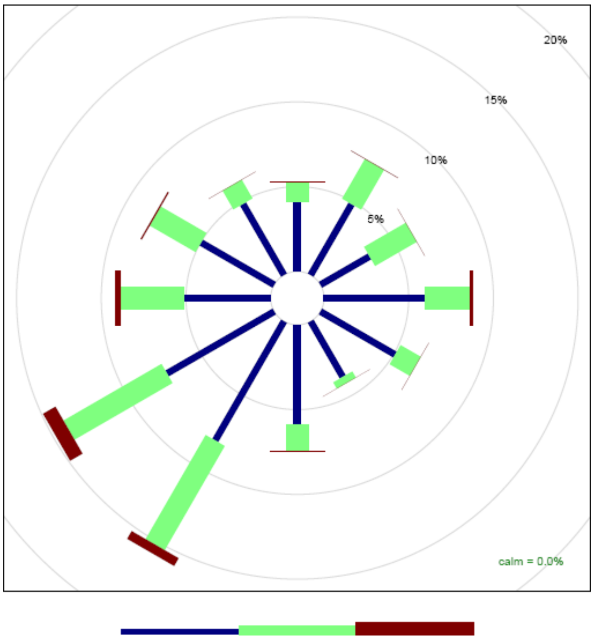

Figure 12. Wind rose for the AQMS LW3 between the 15th September 2010 and 20th September 2011.

Relocation of the AQMS would also allow better characterization of the industrial contribution. As indicated in Section 1, the industrial complex is located NE of the monitoring site. Figure 12 shows the wind rose for LW3. The main wind sector influencing the AQMS is from the south-west (30% frequency) whereas the north-east sector only occurs 13% of the time. A location downwind of the waste treatment facility is suggested to better assess and calculate the contribution of this type of industrial activity on the urban background air quality, but the presence of the railway and the industrial state in the north-east of the waste transfer station (see Figure 1) would make it difficult to locate AQMS here. The AQMS has the advantage of being located near a residential area and the values measured are representative of the potential exposure of residents to the local contribution.

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