Interpretation of Atmospheric Particle Concentrations in London and Helsinki

A contribution to subproject SATURN

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Summary

This paper presents the analysis of particulate matter concentrations measured as PM10 and PM2.5 from urban air quality monitoring networks at two European cities, London and Helsinki for the period comprising years 1997-1999. The data from Helsinki Metropolitan Area includes PM10 concentrations measured at four sites and PM2.5 concentrations measured at two sites. The data for two London sites, one roadside and one urban centre, was obtained from 'The UK National Air Quality Archive' (DETR 2000). The paper investigates the temporal and spatial variation of particulate concentrations also the correlation of these with other air quality and meteorological parameters. The intercity comparisons of the particulate concentrations are also undertaken. Generally in both cities the particulate concentrations in the PM10 and PM2.5 fractions are higher at roadside sites compared to the background sites. The data from both the cities show a clear morning rush hour peak however there are marked differences within city and between cities at the late afternoon/evening peak time. Correlation analysis shows a very high association between PM10 and PM2.5 and other pollutants such as CO and NO_x.

Introduction

There are numerous sources of fine particles in urban centres (QUARG 1996) including natural, road transport, stationary combustion and industrial processes. Road transport nationally can contribute about 25% of PM10 whereas in urban centres the contribution rises to approximately 80-90% (QUARG 1996). The coarse fraction (particles with aerodynamic diameters 2.5-10μm) are generally attributed to the natural sources such as soil, sea salt, biogenic whereas the fine fraction (diameters below 2.5 μm) are mainly generated from the anthropogenic activities involving generally combustion processes or the secondary particulate matter that is produced from the chemical interaction in the atmosphere involving gases again released mainly from anthropogenic activities. Particulate matter, particularly it's fine fraction generally measured as PM2.5, has been associated with hospital admissions and mortality in several studies conducted both in Europe and the USA (Katsouyanni et al., 1997, Pope et al., 1995). It therefore makes it necessary to investigate the sources and processes that result in the observed concentrations of these pollutants in a given space and time.

Objectives

The main objective of this paper is to analyse and interpret the PM10 and PM2.5 measurements at European urban centres in terms of possible sources and processes that control their spatial and temporal distributions.

Results

The descriptive statistics for PM10 and PM2.5 at two London sites for the years 1997-1999 is shown in Table 1. Table 2 shows the correlation of these pollutants with other air quality and meteorological parameters.

Table 1. Descriptive statistics of PM10 and PM2.5

Site	Year/ Particle fraction	Mean mg/m^3			Hourly Maxima mg/m^3		PM2.5 /PM10	Fine/ Coarse
		10	2.5	Coarse	10	2.5		
Bloomsbury	1997	27	19	8	171	156	0.70	2.4
(Urban Centre	1998	23	16	7	241	74	0.69	2.3
	1999	22	15	7	94	73	0.68	2.1
	97-99	24	16	8	171	156	0.67	2
Marylebone	1997	38	24	14	167	106	0.63	1.7
Road	1998	32	21	11	153	74	0.65	1.9
	1999	35	22	13	500	285	0.63	1.7
(Roadside)	97-99	35	22	13	500	285	0.63	1.7

Table 2. Correlation of PM10 and PM2.5 at London Bloomsbury and Marylebone Road

Bloomsbury	Wind Speed	Temp	Global Radiation	CO	NO_x	PM10	PM2.5
PM10	-0.21	0.12	0.12	0.52	0.61	1.00	
PM2.5	-0.33	0.14	0.07	0.55	0.63	0.9	1.00
Marylebone Road							
PM10	-0.19	0.16	0.16	0.49	0.61	1.00	
PM2.5	-0.25	0.15	0.09	0.48	0.61	0.87	1.00

Figure 1shows the diurnal variation of PM10 and PM2.5 and coarse fraction (PM10 - PM2.5) at two London sites. These results suggest that the PM10 and PM2.5 concentrations are significantly higher, 46 and 38 % respectively, at the roadside site compared to the urban centre site. Also there is some difference in the observed PM2.5/PM10 and fine/coarse ratios. These both indicate that the coarse fraction makes a higher proportion of PM10 at the roadside site compared to the urban centre site. This is possibly due to the increases coarse fraction at a roadside site due to resuspension of wear dust caused by the mechanical turbulence of passing vehicles. All the correlation coefficients except the correlation of PM2.5 with global radiation are significant at 95%. At both the sites both particulate fractions show highest correlation among each other and also a very high correlation with CO and NOx, but slightly higher with NOx compared to CO possibly pointing to the impact of diesel vehicles in the origin of these particles. Wind speed has, as expected negative, and temperature a positive correlation coefficient for both the fractions. The global radiation also shows a positive correlation with PM10 possibly indicating the better environment for resuspension due to drier conditions. The diurnal variations at both the sites show a morning rush hour peak that is broader at the Marylebone road site compared to Bloomsbury. However an evening rush hour peak does not seem to be appearing as such. A slight increase in concentration can then be observed around 20.00-21.00 hours probably indicating the traffic resulting from social travel and possibly leaving work late. However this increase is not observed in case of coarse fraction probably due to the fact that the wind speeds are generally low in the latter part of the evening hampering the resuspension of large particles. Unlike PM10 and PM2.5 slight increase is observed in coarse fraction during afternoon hours indicating the influence of day time hours on the resuspension of coarse particles. The location and surroundings of the two London sites are quite similar therefore it can be assumed that the difference in the observed concentrations can mostly be attributed to the traffic.

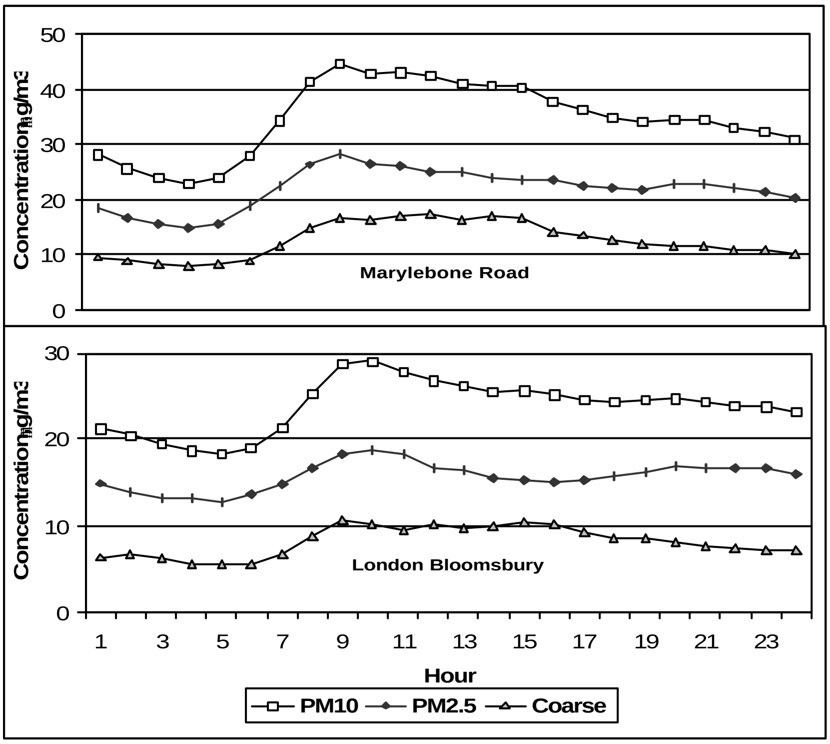

Figure 1. Diurnal variation of PM10 and PM2.5 at Bloomsbury and Marylebone Road

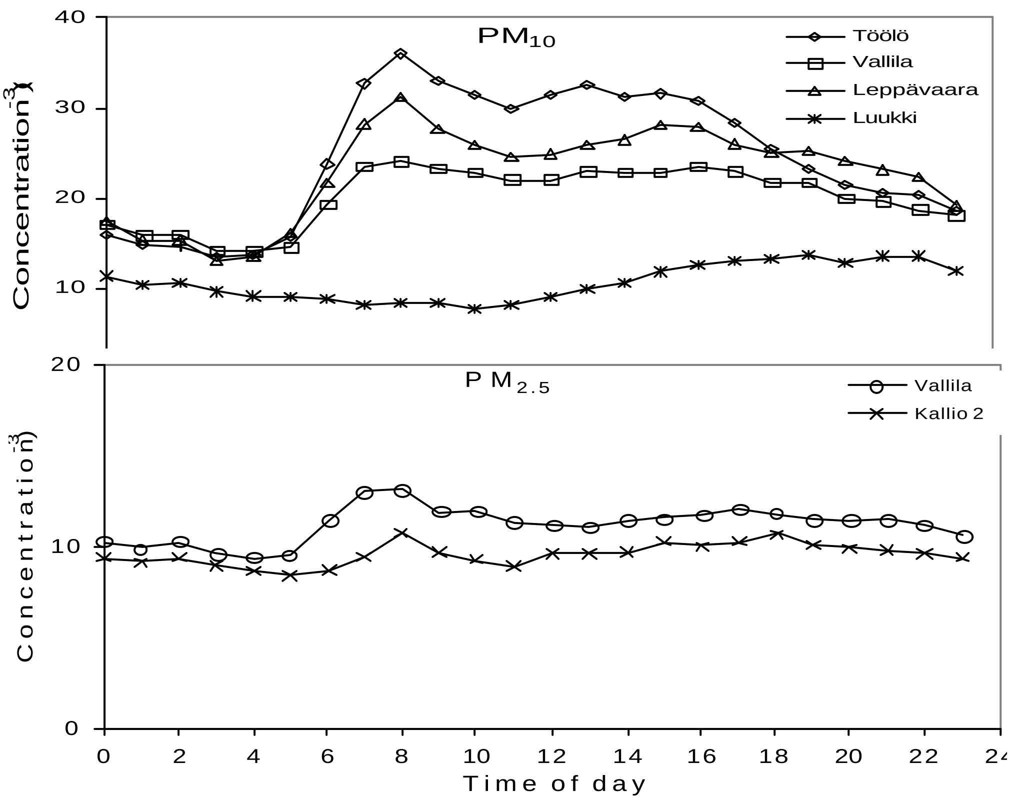

Figure 2. Diurnal variation of PM10 and PM2.5 at various sites in Helsinki

The diurnal variations of PM10 and PM2.5 at the Helsinki Metropolitan area sites are shown in figure 2. The sites shown in the figure can be categorised as: Töölö, Vallila (urban roadside), Leppävaara (suburban roadside), Luukki (rural background) and Kalio2 (urban background). This figure shows that like for London the concentrations at the roadside sites in Helsinki as well are higher by similar magnitude when compared to background sites. The spatial differences in the concentrations at roadside sites can be attributed to the traffic volumes at these sites. The traffic volumes per day at these sites are; Töölö ~ 50000, Vallila ~ 13000, and Leppävaara surrounded by three roads having traffic flows of 11000, 29000 and 63000 vehicles per day. It can be observed that at many Helsinki sites the evening rush hour peak is more prominent and the morning rush hour peak is much sharper as well when compared to London sites. The PM10 and PM2.5 results from Vallila suggest that coarse fraction makes a much bigger proportion (fine/coarse ratio ~1.5) compared to London sites. The enhanced coarse fraction concentrations at the Helsinki sites can possibly be attributed to the use of metal treaded tires and extensive salting and sanding in the extended winter periods. Though London is a much bigger city in terms of area and population the concentration levels are quite comparable.

Conclusions

This paper presents and analyses the results of particulate matter, PM10 and PM2.5, measured at two urban air quality networks of the Europe, that is, London and Helsinki. The results are analysed for the temporal and spatial variation of the particulate matter concentrations. All the sites show a diurnal pattern in both the PM10 and PM2.5 concentrations. The morning rush hour peak is apparent at all the sites, though this peak is much steep at Helsinki sites. Also at many Helsinki sites the evening rush hour peak is also obvious but not in case of the London sites. The correlation analysis at the London sites suggests that PM10 and PM2.5 has the highest correlation among each other and a highly significant correlation with other air quality parameters such as CO and NO_x. On average the particulate matter concentrations are higher by about 40% compared to the sites away from the road. In Helsinki the observed differences at the roadside sites track reasonably well the traffic volumes at these sites. The relative proportions of coarse (2.5-10 PM) and fine fraction ($\leq$ 2.5PM) in the observed concentrations is also analysed. In London coarse fraction is higher at the roadside site compared to background site indicating the importance of the resuspension, mainly coarse particles, due to vehicle turbulence. A Helsinki roadside site when compared with a similar from London shows a higher coarse fraction that possibly can be related to the use of metal treaded tyres and extensive sanding and salting in the winters. The two cities, however different in their sizes, show quite comparable concentrations of particulate matter pollutants.

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