Monitoring of Ultrafine Particle Number Concentration and Other Traffic- related Air Pollutants at One Urban Background Site in Leicester, over The Course of a Year

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This project has received European Regional Development Funding through INTERREG IV B.

Introduction and Objective

Several epidemiological studies have shown a relationship between high number concentrations of ultrafine particles (UFP< 100 nm) and adverse health effects[1]. The objective of this study was to establish validated and consistent data sets of particle number concentrations in Leicester. These data-sets will be used for quantifying the contributions of various pollution sources of ultrafine particles and to develop a method to estimate the number concentration of ultrafine particles in the urban area. These data were collected and will be used in the framework of the EU project JOAQUIN (Joint Air Quality Initiative; www.joaquin.eu) supported by the INTERREG IVB NWE programme. The objectives of the project are to support health-oriented air quality policies and to demonstrate that the newly developed Ultrafine Particle Monitor is able to perform adequately in routine air monitoring networks in NW-Europe. In this study, different techniques for measuring ultrafine particles are intercompared at an urban site in Leicester.

Monitoring Site

The measurements were conducted at the Automatic Urban and Rural Network (AURN, grid ref. SK591028), which is located in the University of Leicester (Fig.1). This site is classified as an urban background site. The sampling inlet was 3.90 m above ground level, The nearest road is the University Road (20 m NW), and the nearest main road is Welford Road (140 m S-SW) with 2x1 lanes (1 in each direction).

Figure 1:A)University of Leicester AURN site and B)the details of the location of the site.

Instrumentation

1. The particle number concentrations (PNC) and size distributions were measured with an ultrafine particle monitor (UFP, TSI model 3031). The Monitor consists of a corona charger, a differential mobility analyser(DMA,) and an electrometer. The measured current is online transferred to a particle number size distribution (20-500 nm) and locally stored. For the UFP 3031 the size classes have been defined (Table 1) as follows:

Table1: Size classes of UFP 3031

Classes	Range(nm)
Class 1	20-30
Class 2	30-50
Class 3	50-70
Class 4	70-100
Class 5	100-200
Class 6	>200

2. The total particle number concentrations (TNC) were measured with a water-based condensation particle counter (W-CPC, TSI model 3783). The Model 3783 is a continuous-flow, water-based, CPC that detects particles down to 7 nm.

3. Black Carbon (BC) mass was derived by light absorption using a Multi-Angle Absorption Photometer (MAAP, Thermo Scientific Model 5012). In this instrument, particles are deposited on a quartz fibre filter. A continuous 670 nm laser is passed perpendicular through the filter matrix and the transmission is measured.

4. Oxides of nitrogen (NO, NO_2 and NO_X) were measured by using a chemiluminescence analyser (Thermo Scientific™ Model 42i NO-NO2-NOx Analyser). It has a single chamber, single photomultiplier tube design that cycles between the NO and NO_X modes.

Results

Size distributions

Figure 2 shows seasonal particle number size distributions at the AURN site from Dec-2013 to Nov-2014. All profiles for all seasons showed the same trend. From 50 nm to 200 nm particle number concentrations decreased. The highest particle number concentrations were observed in the size range 30-50 nm. In addition, particles larger than 50 nm were observed lower in summer than the cool season[2].

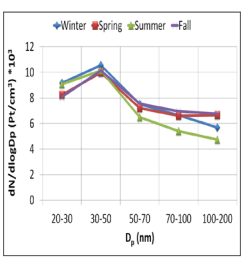

Figure 2: Particle number size distributions.

Temporal Variations

Seasonal and diurnal variations of UFP (20-100nm), NO_2, NO, and BC are shown in Figure 3, high concentrations of the pollutants were observed in winter than in summer, also two peaks were observed in the working days which are due to the morning and afternoon rush hours[2], The morning peak still present in summer months, but with lower absolute values of UFP than in winter, might be related predominantly to particles directly emitted by traffic and to the more favourable conditions of atmospheric dispersion[2].

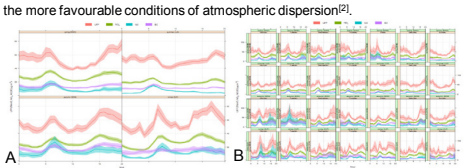

Figure 3: A)Seasonal and B)Weekdays variations for UFP,NO_2, NO, and BC (Dec13-Nov14).

Overall Statistics

Statistics of UFP, ACCU, TNC, NO_X, and BC are shown in Table 2. The general seasonal pattern observed could be due to the weaker atmospheric convective processes in winter. This variation for UFP, as well as for other, pollutants, was found more clear during the cool season than in summer[2].

Table 2: Statistic of particle number concentration(Pt/cm³), NO_X and BC(µg/m³) measured in Winter and Summer 2014

Particle Size	Polluts.	Average	Median	95th percentile	S.D.	Data capture %
Winter						
20-100nm	UFP	5.7×10^3	4.4×10^3	14.1×10^3	4.4×10^3	95.40
100-200nm	ACCU	1×10^3	0.6×10^3	2.9×10^3	1.03×10^3	95.40
7-1000nm	TNC	8.9×10^3	7.3×10^3	20×10^3	5.9×10^3	95.40
	NO_X	38.3	27.4	99.66	37.53	100
	BC	1.44	0.97	4.1	1.3	37.75
Summer						
20-100nm	UFP	5.2×10^3	4.6×10^3	11×10^3	2.9×10^3	99.93
100-200 nm	ACCU	0.8×10^3	0.7×10^3	1.6×10^3	0.55×10^3	99.93
7-1000nm	TNC	8.2×10^3	7.6×10^3	15×10^3	3.9×10^3	52.98
	NO_X	25.8	22.7	58.2	16.7	100
	BC	1.13	0.97	2.4	0.76	99.30

Traffic Effects

From the results showed in Table 3 it can be argued that the correlation between UFP and other traffic related pollutants during rush hour are stronger than the rest of the day probably due to the traffic intensity. Figure 4 shows the relationship of UFP with BC, NO_2 and NO and colour-coded by the Traffic, and also diurnal variations of UFP and traffic related-pollutants concentrations are shown in Figure 5. High UFP concentration was observed starting at 6:00-7:00, peaking at 8:00, and disappearing as the mixed layer developed(Fig.5). The increased UFP at 8:00 is consistent with NO_2,NO and BC, suggesting that those particles are produced most likely from morning rush-hour traffic.

Table3: Half-hourly Pearson Correlation (r) , and correlation coefficient (R^2), of UFP vs co-pollutants in two seasons.

		Day Hours (9:30-19:00)		Rush Hours (6:00-9:00)	
	UFP	r	R^2	r	R^2
Winter NO_2, and NO 6th Jan -7th Feb 2014 BC and Traffic Dec-2014 CO 10th Jan- 9th Feb 2015	BC	0.95	0.9	0.98	0.96
	CO	0.25	0.061	0.97	1
	NO_2	0.81	0.66	0.84	0.71
	NO	0.5	0.25	0.76	0.57
	Traffic	0.27	0.18	0.85	0.72
Summer 9th Jun – 11th July 2014	BC	-0.4	-0.1	0.48	0.29
	CO	NA	NA	NA	NA
	NO_2	0.54	0.29	0.83	0.68
	NO	-0.77	-0.6	0.83	0.69
	Traffic	0.38	0.14	0.73	053

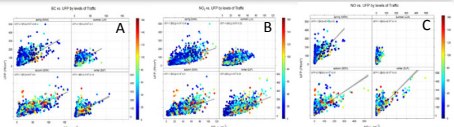

Figure 4: Scatter plots of UFP vs A)BC, B)NO_2 and C)NO by levels of Traffic Intensity split by season (Dec13-Nov14).

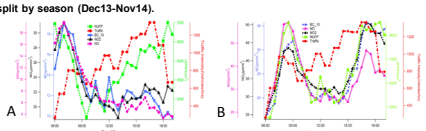

Figure 5: Diurnal variations of UFP, BC, NO_2 and NO and Traffic Intensity in November(B) and Jun-July(A) 2014.

Wind Dependence

Changes in wind speed and direction have been demonstrated to dramatically alter the pattern of total particle number concentration versus distances from the roads[3]. Wind conditions generally have a significant impact on particle number concentration in urban environments based on wind strength and wind direction. Polar plots of ultrafine particle number concentrations as a function of wind speed and direction allow for the identification of local or external sources of this pollutant[4]. Figure 6 clearly shows highest UFP and TNC concentrations when the wind is from south, south-west, and north-west probably due to the University and Welford roads and domestic combustion . In addition, UFP and TNC high concentrations were observed at low wind speed this is typical of the urban environment.

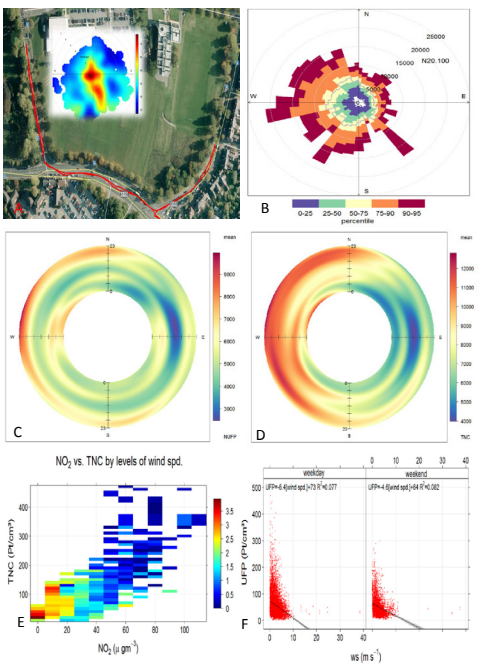

Figure 6: A)Polarplot of UFP, B)Percentile Rose plot of UFP, Polar Annulus plots of C) UFP and D)TNC, E)Scatterplot of TNC vs NO_2, F)Scatterplots of UFP vs WS (Dec13-Nov14).

Conclusions and Future Work

- A clear seasonal and daily pattern was found could be considered the result of the motor vehicle emissions combined with a lower mixing layer height and low ambient temperature in winter[5] , with higher values during the cool season and peak concentrations during rush hours.
- The results of this study suggest that there is high relationship between UFP and other traffic related pollutants(CO, BC, NO_X) for the morning rush hour. Our results suggest that the local traffic exhaust emissions were a major contributor of the pollution of ultrafine particles in Leicester urban atmosphere.
- Sources of UFP could be identified with most of them coming from the south, south-west, and north-west, corresponding to the road traffic and domestic combustion emissions.
- Future work will consist of carrying on with the further analysis of the UFP across North-West Europe to broaden the understanding of air quality across this region.

Acknowledgments: I would like to thank HCDP for funding my PhD. I would also like to thank my supervisor Prof Paul S. Monks for presenting me with this project. This work was partly funded by the INTERREG IVB NWE programme.

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