Summer-autumn air pollution in León (Spain): changes in the aerosol size distribution and effects on the respiratory tract

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INTRODUCTION

In urban areas there are important sources of fine and ultrafine particles: traffic, industrial activity, residential wood and/or coal combustion, etc. León, Spain, is characterized by the absence of large emitting industries and the main source of particulate emissions is considered to be vehicular traffic during all the year. However, an important number of residential devices that use coal as fuel are still present, also natural gas and gasoil are used for heating and hot water during all the year. As a consequence, in autumn, winter and even spring there are remarkable emissions from this source. The aim of this study is to analyze the temporal variation of aerosol size distribution in León from August to October 2012 in order to identify changes in the aerosol concentration associated with the summer- autumn transition. Furthermore, the influence of these aerosols in the respiratory tract by the study of inhalable, thoracic, respirable and tracheobronchial fractions was analyzed.

STUDY AREA AND METHODOLOGY

León is a city in northwestern Iberia (42º 36′ N, 05º 35′ W and 838 m above sea level) with a population of more than 140,000 inhabitants. The climate is of the Mediterranean type with continental features. The aerosol sampling was carried out in the Secondary School IES Ordoño II, in the San Juan de Sahagún Avenue (Fig. 1). The measuring probe was installed 1.5 m above the floor, directed towards a street. The study period comprises from 1st August to 23rd October, 2012.

The particle number size distributions were measured using a passive cavity aerosol spectrometer probe (PCASP-X) (Fig. 2). Particle size spectra were continuous monitoring in 31 discrete channels (size ranges between 0.1 and 10 µm).

Fig. 1. Location of sampling site

Fig. 2. Optical particle counter (PCASP-X)

RESULTS

The number of particles (N_T) increased from August to October, (1000 ± 600 to 1500 ± 1000 particles cm^{-3}, respectively, Table 1) mainly due to lower traffic intensity during summer holidays and the absence of heating emissions . Furthermore, in summer, a lower concentration was registered due to an increase in the boundary layer thickness that enhances dispersion (Calvo et al., 2008). The Count Median Diame (CMD) was similar in August, September and October (Table 1).

Table 1. N_T and CMD for different situations during the summer-autumn transition: a) months, b) weekdays/weekend, c) days of week.

		Particle number distribution		
		N_T (cm^{-3})	CMD (µm)	σ_g
a)	August	1000 ± 600	0.14 ± 0.02	1.4 ± 0.1
	September	1200 ± 700	0.14 ± 0.02	1.4 ± 0.1
	October	1500 ± 1000	0.14 ± 0.02	1.4 ± 0.0
b)	Weekdays	1200 ± 800	0.14 ± 0.02	1.4 ± 0.1
	Weekend	1100 ± 700	0.14 ± 0.02	1.4 ± 0.0
c)	Monday	1300 ± 900	0.14 ± 0.02	1.4 ± 0.0
	Tuesday	1300 ± 800	0.14 ± 0.02	1.4 ± 0.0
	Wednesday	1100 ± 700	0.14 ± 0.02	1.4 ± 0.1
	Thursday	1200 ± 800	0.14 ± 0.02	1.4 ± 0.1
	Friday	1200 ± 700	0.14 ± 0.02	1.4 ± 0.1
	Saturday	1200 ± 800	0.14 ± 0.02	1.4 ± 0.0
	Sunday	1000 ± 600	0.14 ± 0.02	1.4 ± 0.0

The particle size distribution shows a bimodal profile, with a first fine or accumulation mode (CMD < 1 µm) and a small fraction corresponding to a second fine mode or a coarse mode (CMD ≥ 1 µm) (Table 2). The monthly evolution of the particle numbers shows that 99% of the particles have diameters less than 0.5 µm, which may indicate that the main source of aerosol is road traffic (Calvo et al., 2013).

Table 2. N_T, CMD and geometric standard deviation (σ_g) of the particles size distribution, for different situations during the summer-autumn transition: a) months, b) weekdays/weekend, c) hourly intervals for weekdays and weekend, for two modes.

			First Fine Mode			Second Mode		
			N_T (cm^{-3})	CMD (µm)	σ_g	N_T (cm^{-3})	CMD (µm)	σ_g
a)	August		303	0.09	1.74	0.22	1.65	1.83
	September		407	0.08	1.80	0.38	1.06	2.07
	October		573	0.08	1.71	0.76	0.59	1.94
b)	Weekdays		431	0.08	1.76	0.60	0.73	2.30
	Weekend		314	0.09	1.73	0.23	1.08	1.65
c)	Weekdays	0000-0500 UTC	180	0.10	1.76	0.12	1.81	1.63
		0500-1000 UTC	657	0.08	1.74	0.95	0.56	2.47
		1000-1500 UTC	474	0.08	1.71	1.16	0.41	2.76
		1500-2000 UTC	456	0.08	1.69	1.06	0.42	2.82
		2000-0000 UTC	290	0.09	1.78	0.20	1.59	1.84
	Weekend	0000-0500 UTC	193	0.11	1.72	0.25	1.30	1.85
		0500-1000 UTC	363	0.09	1.73	0.27	1.15	1.75
		1000-1500 UTC	293	0.09	1.72	0.51	0.49	3.36
		1500-2000 UTC	410	0.08	1.71	0.27	1.02	1.74
		2000-0000 UTC	314	0.09	1.76	0.45	0.86	2.09

As summer progresses to autumn, the N_T of fine mode increases and the CMD decreases. There are more particles between 0600 and 1000 UTC and between 1700 and 1900 UTC, in coincidence with traffic rush hours. The highest particle sizes are registered between 0600 and 0900 UTC on weekdays reaching the maximum values of 0.16 µm.

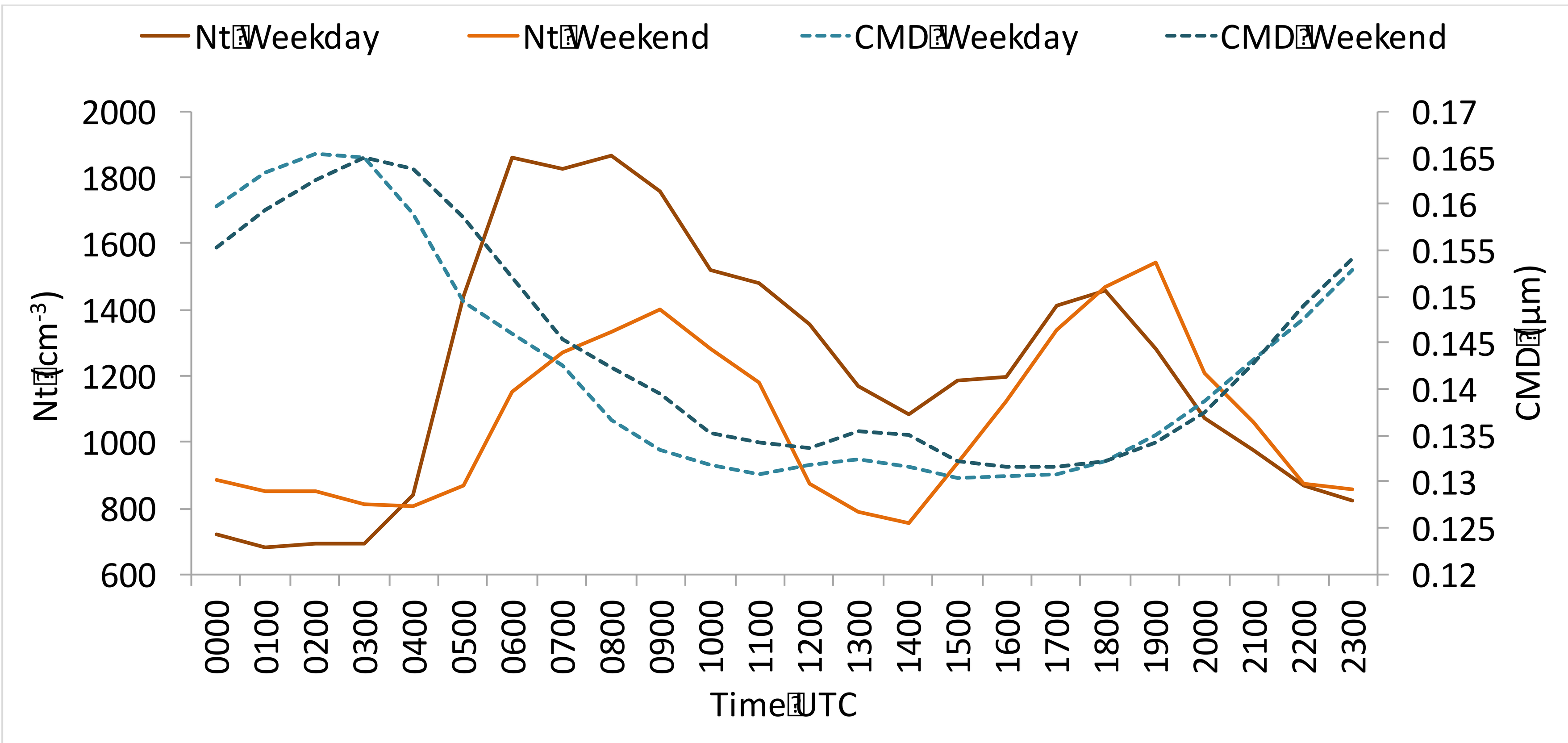

Fig. 3. Hourly variation of the N_T and *CMD*.

The percentage of particles that does not traverse any non-ciliated airway and they reached the trachea and bronchi varied between 20% and 38%, with the lowest value in October. For the respirable fraction, in the high-risk population like children, elderly and weak people, the best month is August with 6 µg m^{-3} and the worst is October with 9 µg m^{-3} of particles that came to reach the alveolar zone (Table 3).

Table 3. Inhalable, thoracic, tracheobronchial and respirable mass fractions in healthy adults and high risk population (children, frail or sick people) deposited in the respiratory tract for different situations during the summer-autumn transition: a) months, b) weekdays/weekend, c) hourly intervals for weekdays and weekend.

		Inhalable Fraction	Thoracic Fraction	Tracheobronquial Fraction		Respirable Fraction	
				Healthy adult	High risk	Healthy adult	High risk
		µg m^{-3}	µg m-3	µg m^{-3}	µg m^{-3}	µg m^{-3}	µg m^{-3}
a)	August	41± 46	27 ± 30	17 ± 19	21 ± 23	10 ± 11	6 ± 7
	September	45 ± 36	29 ± 23	18 ± 14	21 ± 17	12 ± 9	8 ± 6
	October	28 ± 20	19 ± 13	7 ± 5	9 ± 6	12 ± 8	9 ± 7
b)	Weekdays	42 ± 43	27 ± 27	16 ± 16	19 ± 19	11 ± 11	7 ± 7
	Weekend	36 ± 32	24 ± 22	14 ± 12	17 ± 15	11 ± 9	7 ± 6
c)	Weekdays						
	0000-0500	36 ± 42	19 ± 22	11 ± 12	12 ± 14	9 ± 10	7 ± 8
	0500-1000	53 ± 40	31 ± 24	17 ± 13	21 ± 16	14 ± 11	10 ± 8
	1000-1500	38 ± 28	27 ± 20	16 ± 12	20 ± 15	11 ± 8	6 ± 5
	1500-2000	44 ± 57	30 ± 39	19 ± 25	24 ± 31	11 ± 15	7 ± 9
	2000-0000	41 ± 39	26 ± 24	16 ± 15	19 ± 18	10 ± 9	6 ± 6
	Weekend						
	0000-0500	42 ± 42	24 ± 25	14 ± 14	16 ± 16	11 ± 11	8 ± 8
	0500-1000	42 ± 41	25 ± 24	14 ± 14	17 ± 16	11 ± 11	8 ± 8
	1000-1500	26 ± 18	16 ± 11	9 ± 6	11 ± 7	7 ± 5	6 ± 4
	1500-2000	32 ± 23	18 ± 14	10 ± 7	11 ± 8	9 ± 6	7 ± 5
	2000-0000	35 ± 10	20 ± 10	11 ± 5	13 ± 7	9 ± 4	7 ± 3

CONCLUSIONS

- As summer progresses to autumn the particle number increases, the main raisons for the increase in the particle number are the traffic intensification after summer holidays, the lower dispersion caused by the low boundary layer thickness and the start of the use of the domestic heating devices in autumn.
- For the respirable fraction in healthy adults, the higher values are obtained in September and October (12 µg m^{-3}), and between 0500 to 1000 UTC on weekdays on Monday, Friday and Saturday (14 µg m^{-3}).

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