Exposure to ultrafine particles in indoor and outdoor school environments across Barcelona (Spain)

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Keywords: particle number, lung-deposited surface area, chemical characterization, urban air quality.
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The direct link between exposure to atmospheric particulate matter (PM) and adverse health outcomes has been widely proven in the literature (Lim et al., 2012). Studies highlight the dependence of this relationship with particle size, concluding that particles with aerodynamic diameter <100 nanometres (ultrafine particles, UFPs) show a higher potency for adverse health effects because of their ability to penetrate deeper into the respiratory tract and to translocate to other organs (Oberdorster, 2001). There is little information on the trend in UFP in European urban atmospheres, but the increased load of diesel vehicles and recent data suggest an upward trend.

Major knowledge gaps exist currently regarding the health hazardous effects of exposure to fine and ultrafine atmospheric particles of outdoor and indoor origin, in indoor environments. This is especially true for specific risk groups such as children. The early school years are considered an important window for brain development, but also a long period of vulnerability given that susceptibility to environmental threats is elevated.

Population exposure to airborne pollutants is usually considered to take place in outdoor environments. However, it is estimated that adults spend approximately 60-80% of their time indoors (at least 40% in schools, for children).

While most of the available studies on UFP focus on particle mass, there is still very little information on the indoor/outdoor relationship for other parameters such as particle number (N), lung-deposited surface area (LDSA) or size-resolved chemical composition. The main goal of the present work is to characterise child exposure to chemically-characterised ultrafine particles of outdoor and indoor origin in schools, with special attention to indoor and outdoor concentrations in terms of particle number and particle surface area.

Indoor and outdoor sampling of UFP concentrations, as well as monitoring of particle number, size and LDSA, was carried out at 38 primary schools in Barcelona, within the framework of the ERC Advanced Grant BREATHE. Particle number, LDSA and mean size were simultaneously monitored in indoor and outdoor air by means of DiscMini (Matter Aerosol) instruments, with a 10-minute time resolution from Monday to Friday morning. Particles coarser than 700 nm were removed by an impactor at the inlet.

UFP concentrations were sampled by means of PCIS impactors (Sioutas Personal Cascade Impactors), using 37mm and 25 mm Pall quartz-fibre filter substrates. Two impactors were used respectively in the indoor and outdoor environments (4 PCIS in total per school). Three cut-off sizes are used: >PM2.5, PM0.25-2.5, and PM0.25. The sampling duration was 8 hours per day (9-17h, school hours) over 4 consecutive days, amounting to a total of 32 hours per filter. The flow was set to 9 lpm. The samples obtained were chemically characterised, determining >65 elements and components: a fraction of the filter was acid digested and the resulting solution was analysed by inductively coupled plasma mass spectrometry (ICP-MS) for trace elements and by inductively coupled plasma optical emission spectrometry (ICP-OES) for major elements; one fraction was analysed for OC and EC by thermo-optical analysis, and a remaining fraction was leached and analysed by ion chromatography. Ventilation conditions (e.g., open or closed windows) were recorded.

A summary of results regarding N, LDSA and mean particle size are shown in Table 1. Results on size-resolved particle chemical speciation will be presented. Size-resolved chemical speciation allowed to observe the prevalence of metals (Zn, Cu, V) in the ultrafine fraction. It was observed that size fractionation depends on indoor vs. outdoor sources. A relative decrease in ultrafine particles indoors was detected with respect to outdoor air, and was ascribed to losses by diffusion.

Table 1. Ranges obtained for particle number (N), average size and lung-deposited surface area (LDSA).

INDOOR	**Nr. schools**	**Mean**	**Min**	**Max**	**Std.Dev.**
N ($\#\cdot cm^{-3}$)	37	17.209	6.196	33.523	6.493
Size (nm)	37	41	30	54	6
LDSA ($\mu m^2\cdot cm^{-3}$)	37	35	13	71	14
OUTDOOR					
N ($\#\cdot cm^{-3}$)	35	23.824	9.193	78.004	13.296
Size (nm)	35	36	27	54	6
LDSA ($\mu m^2\cdot cm^{-3}$)	35	44	24	115	18

This work was supported by the European Research Council (ERC) Advanced Grant BREATHE and national projects IMPACT (CGL2011-26574) and VAMOS (CGL2010-19464/CLI).

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