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Size Partitioning of Airborne Particles to Compare their Proinflammatory Effect in Airway Epithelial Cells

Paris background aerosol is almost exclusively composed of fine (PM 2.5; PM 1) and ultra fine (PM 0.1) particles, originating mainly from combustion processes including traffic exhausts. Epidemiological and experimental investigations underlined the role of the aerosol size, in particular the ultra fine one.

The aim of the present study was to investigate which size-fraction of the urban particulate matter is the most relevant regarding to the biological effect considering the proinflammatory response of airway epithelial cells in vitro. This response is characterized by the release of mediators that would explain the inflammation observed in exposed subjects.

Human bronchial epithelial cells (16HBE) and primary culture of nasal epithelial cells (HNE) that are the main target cells of airborne particles were exposed to the different size-fractions. The release of GM-CSF, a cytokine involved in allergic process was used as a pro-inflammatory biomarker of PM exposure, heme oxygenase-1 (HO-1) expression as an oxidative stress biomarker and the cytochrome P450 1A1 (CYP1A1) activity, an enzyme that metabolizes xenobiotics, was used as a biomarker of polyaromatic hydrocarbon (PAH) bioavailability.

Downtown Paris, four co-located 13-stage Dekati cascade impactors running in parallel were used to selectively collect particles from 30 nm to 10 µm on polycarbonate filters and were allocated to biological and physico-chemical (black carbon, particulate organic matter and water soluble organic compounds, major ions, PAH) investigations. 11 samplings were conducted in order to investigate whether the seasonal variability (summer and winter) and diurnal evolution related to photochemistry of the urban aerosol composition modulate the biological effects of some or all size-fractions.

In vitro biological assays were conducted with particles from pooled stages (1 to 3 representing ultra fine fraction (0.1-0.03µm), 4 to 7 the (1-0.1µm), 8 to 9 the (2.5-1µm) fine fraction and 10 to 13 the (10-2.5µm) coarse fraction). Particles were recovered from collection filters by brief sonications directly in the same volume of cell culture medium for each size-fractions. Two experimental strategies were used: cells were exposed for 24 hours either at Isovolum of particles suspension in order to respect the proportion of the different size-fraction in the sampled-air volume or at isomass.

When cells are exposed to an isovolume of particles suspension, the highest GM-CSF secretion was induced by PM1-0.1 that is the most important fraction in Paris background aerosol (up to 71% of the total PM10 mass). With a cell exposure at an isomass of particles, GM-CSF secretion was significantly induced by fine and ultra-fine particles with a close-dependent increase from 1 µg/cm² (5µg/mL) to 10µg/cm², without inducing any cytotoxicity. Whatever the season or diurnal sampling, the finer the aerosol fraction, the higher the GM-CSF secretion was, whereas coarse particles displayed no or fewer effect. Moreover, endotoxins were not involved in the ultrafine particle-induced GM-CSF secretion whereas they partially contributed to the fine particle ones as assessed by the use of endotoxin neutralizing recombinant protein. GM-CSF expression was correlated to HO-1 expression. Considering PAH bioavailability, PM1-0.1 from winter samples induced the higher CYP1A1 activity increases as the size decreases with summer samples.

Chemical analyses enlightened the major presence of carbonaceous species in Paris aerosols especially in the ultrafine and fine fractions where PAH are also predominant (90% in these fractions).

To conclude, we observed that the proinflammatory response of bronchial epithelial cells in vitro was closely related to particle size with ultrafine particles exhibiting the highest effect.

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