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Age-related dose deposition of particulate matter in human respiratory tract: findings from a birth cross-sectional study in Portugal

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Indoor air pollution remains a great global concern. Particulate matter (PM), namely ultrafine particles (aerodynamic diameter smaller than 0.1 μm ; UFP), is considered as one of the most health-relevant air pollutant for various subpopulations, one of which is children. Knowledge on the specific dose deposition of PM may provide a critical link for better understanding of the relationship between individual exposure and the respective health effects. Mathematical models have proven to be important tools for analysing PM dose deposition in the respiratory tract providing relevant data for health risk assessment, source apportionment of human lung burdens and control strategies purposes. This work aimed to estimate the deposition dose of different PM sizes at different age categories. Inhalation dosimetry estimations were carried out using the multiple-path particle dosimetry model (MPPD, v3.04). Age specific 5-lobe model with uniform expansion was adopted in the present study. Total, regional and lobar deposition was estimated for 3-months' old children (corresponding the infants), 21–30 years, 31–40 years and 41–55 years old female adults. Real-time sampling of PM₁₀, PM_{2.5} and UFP was conducted in 65 homes located in Porto Metropolitan Area between May 2018 and February 2019. 48-h PM₁₀ and PM_{2.5} were measured by DustTrak™ DRX Aerosol Monitors (Model 8533, TSI Inc. MN, USA), while Portable Condensation Particle Counters (P-Trak™ Model 8525, TSI Inc. MN, USA) were used for 8 h sampling of UFP (particles size: 20-1000 nm). Multi-path particle dosimetry model was performed based on participant' specific data to estimate deposition fractions of PM with different sizes. The highest deposited fraction for PM₁₀ and PM_{2.5} was obtained in the age group of 41 to 51 years' respiratory tract, whereas their lowest deposition fraction was observed in 3 months old infants. Inversely, the highest and lowest deposited fractions of UFP were recorded in 3 months old infants and in 31-40 years old age airways, respectively. Through nasal breathing PM₁₀ was highly deposited in the head (87% of total deposition fraction in all age groups) when compared to other PM fractions. Also for all age groups, pulmonary region was highly deposited by both UFP (43%) and PM_{2.5} (39%). PM₁₀ and PM_{2.5} depositions were greater in adults than in newborns (0.96 and 0.75 vs. 0.86 and 0.60). This difference may be due to many factors, such as physical mechanisms, particle size, as well as due to airflow and anatomical and physiological factors. Across all age categories, lower lobes received maximum deposition than the upper and middle lobes. Deposition fraction in a lobe was proportional to the volume of air passing through that lobe, as lower lobes (i.e. with higher volumes) experienced higher PM deposition; middle lobes with smaller volumes thus shown a lower deposition. PM_{2.5} dominated the deposition in all five lobes of infant, children and adults. This fine fraction deposition in lobar regions can lead to decreased lung function, increased development of chronic obstructive pulmonary disease

and respiratory morbidity. This study represents an important step towards a better understanding of human exposure to PM for a consequent reduction of health risks. The application of the multi-path particle dosimetry model has demonstrated that smaller particles (PM_{2.5} and UFP) tend to deposit in pulmonary area while PM₁₀, are mainly found in head region, namely in infants. Considering the lung lobe specifically, higher PM deposition was observed in the right lobes than in the left one.

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