Modeling Differences in How Particles Deposit in the Lungs of Children and Adults

“Inhalation of airborne particles poses a potential health risk to various groups, one of which is children. Our research and modeling revealed significant age-related differences in lung deposition and expands our quantitative understanding of the factors that make children potentially more susceptible to particulate exposures.”

—Dr. Bahman Asgharian, CIIT Centers for Health Research

Recent studies suggest that children are susceptible to airborne particulate matter (PM) exposure. Adverse effects associated with PM exposure include chronic cough, bronchitis, and chest illness. Children with a history of asthma often show elevated levels of respiratory symptoms, including increased hospital admissions, when they live in areas with high particulate pollution. PM exposure is also associated with increased prevalence of school absence. In addition, there is concern that respiratory problems and other diseases in adults may have started during childhood. Thus, individuals exposed to PM when they are children may be more sensitive to PM during adulthood.

Factors contributing to childhood susceptibility to PM include aspects of exposure as well as biological sensitivity. For example, children tend to have greater exposure to air pollution because they typically spend more time outdoors compared to adults, and their increased breathing frequency compared to adults results in a greater mass deposited per unit area. Children may also have a greater sensitivity to PM compared to adults due to defense mechanisms or detoxification pathways not being fully developed.

Upon inhalation, particles that are not filtered out by the nose or mouth can be deposited in different areas of the lung, where they are absorbed or cleared by different biological mechanisms. The quantity of PM delivered to the lungs depends on particle characteristics (e.g., size, shape, density, and tendency to absorb water), physiological factors such as the route and depth of breathing, the structure of the lung, and the efficiency of clearance mechanisms. For adults, researchers have developed models that predict lung deposition, clearance, and retention to support risk assessments for PM and other airborne compounds of interest (e.g., metals).

Lung deposition models for children, however, have been lagging behind those available for adults. CIIT Centers for Health Research (CIIT), with funding from the American Chemistry Council’s Long-Range Research Initiative (LRI), recently extended its state-of-the-art lung dosimetry model to include children of different ages based on measured lung anatomy data.
CIIT added to its existing Multiple Path Particle Dosimetry (MPPD) model the capability to model deposition in children of various ages. The MPPD model can incorporate the complex anatomy of the branching structure of the lung and can calculate deposition at the individual airway level for a range of particle sizes. (See LRI Perspective “Predicting the Fate of Particles in the Respiratory Tract.”)

Based on measurements of children’s airways, the researchers developed lung geometry models for individuals aged three months to 21 years. CIIT scientists then modeled the deposition of particles of different sizes, assuming at-rest breathing patterns, and evaluated age-related differences in lung deposition.

Previous inhalation dosimetry models for children were based on assumptions that children’s lungs were miniature versions of adult lungs. The data compiled and evaluated in the MPPD model show that this is not the case (see the figure “Children’s Lungs Aren’t Just Smaller”). The MPPD model’s predictions are more accurate than previous models that were based on adult lung geometry, thereby reducing uncertainties about intersubject variability. The model is available for free at www.ciit.org/techtransfer/tt_technologies.asp.

CIIT found significant differences between deposition patterns in children and adults. Adjusting for differences in lung size, infants had the highest deposition fraction, which means they deposit the greatest amount of particles per unit area of lung surface. This variation from adults decreases as children get older, such that by adolescence children are no longer different from adults relative to the fraction of particles deposited in the lung.

Because there are few data on any differences between children and adults in the clearance of particles, how children and adults may differ in retained dose is an area in need of research. Until such data are available, assumptions must be made about clearance rates as a function of age in order to use the MPPD model to examine retained particle dose for children compared to adults.

Various age-related analyses that can be done with the MPPD model will help improve risk assessments for inhaled particles. Quantitative, data-driven dose estimates generated by the MPPD model can be used to refine or replace uncertainty factors used to establish exposure levels that are protective of susceptible populations such as children.


