

Integration of two mathematical models for monitoring of biological doses from inhalation exposure to nano and fine particles in industrial workplace

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Inhalation of nanoparticles is one of the great concerns in the area of nanomaterials and nanotechnology safety. Characterization of worker dose includes the chemical and physical characterization of particles, the determination of inhaled doses, and their biological characterization. We present a study addressing these steps for the case of industrial manufacturing of detergent and cosmetics (powders) by combining two models of consecutive simulation: (i) for lung deposition and (ii) for lung clearance. Both models are transformed into computational codes using FORTRAN.

Internal dosimetry is accomplished with an appropriate biomathematical model, consisted of two sub-models, which calculates with a full mechanistic description lung deposition with continuous clearance. The first model is a mechanistic, respiratory deposition model including aerosol and breathing dynamics (Mitsakou et al., 2005 & 2007). It is based on a one-dimensional representation of the aerosol flow along the whole respiratory tract, i.e. the extrathoracic part and all generations of the thoracic part. The second model is a compartmental, mechanistic, model that calculates retention/translocation of deposited particles. (Tran et al., 1999 & 2007). The considered mechanisms include phagocytosis, macrophage life cycle, interstitialization and transfer to the lymph nodes. The integrated model of coupled deposition and clearance ultimately provides effective biological doses to the lung, namely deposited amount minus cleared amount.

Experimental monitoring data of airborne exposure levels during detergent manufacturing in a major chemical plant are used as input to the model to translate the exposure concentrations to effective biological doses to the lung of the workers. In determining internally delivered biological doses worst case scenarios are assumed, i.e. workers are not using protective means.

We examined if measurements made by convenient, inexpensive on-line monitors based on light scattering can assess adequately the particles concentration and size characteristics in the workplace (i.e. close to the gravimetric methods).

Focus is given in assessing the impact on the calculated dose of the measurement uncertainty when

monitoring is based on optical ("user-friendly") aerosol measurements.

Dosimetric data are numerically generated by simulating chronic exposure conditions, i.e. running the model over the working life of a worker assuming typical exposure scenarios based on the measurement data (Figure 1). Such chronic simulated doses can be compared with DNELs (derived no-effect limits) from in-vitro biological assays and, therefore, recommend possible safe workplace exposure levels.

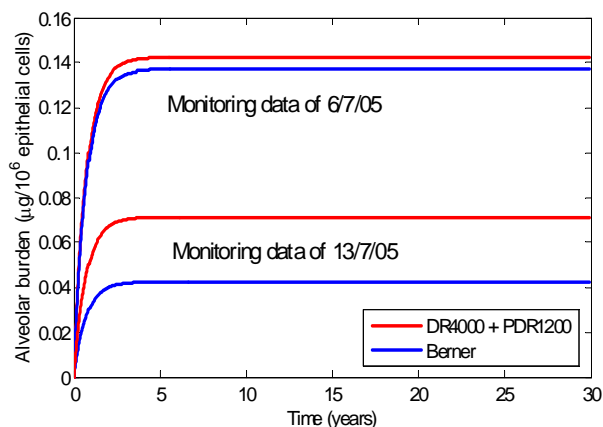


Figure 1. Time evolution of the alveolar burden, under continuous deposition and clearance, assuming a chronic exposure scenario for over a typical working period of 30 years.

The present study illustrates the effectiveness of combining the two mathematical models. Furthermore, we illustrate the feasibility of combining mechanistic mathematical modelling with data from user-friendly monitors and data from in-vitro toxicological assays to derive limits and assess risk.

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