Enhanced Condensational Growth in the Upper Airways Induced by Specific Climatic Conditions as a Major Factor for Increased Deposition of Inhaled Aerosols

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How long lung inhalation models and aerosol dosimetry studies used the possibility of supersaturation and enhanced condensational growth?

Haddrell et al. (2015) concluded that, “the sensitivity to the ambient RH is typically not considered in lung inhalation models; in the literature review made during the preparation of this manuscript, no articles discussing this point were found.” Such a state of affairs has not changed in recent years.

Thus, most CFD studies do not consider the possibility of air saturation in the human airways, and they do not even consider the sensitivity to ambient RH; this point is very important for the understanding of the whole scale of the problem.

For reference, the problem with the classical view of the deposition of ambient aerosols in human airways is that it is based on the postulate that under any weather conditions, the conditions in human airways will be normal (RH=90-99.5%; T=30-37°C) (see the related review in Elad et al., 2008)). Under such “classical/normal” conditions in the airways, the hygroscopic and condensational growth of inhaled particles is limited by a growth factor of 1.3-1.7 (with a maximum of 4 for rare).

However, this is not always true (see Table) and conditions in the airways can be supersaturated (RH=100%) and this can lead to unlimited and enhanced condensational growth (growth factor of more than 10-20).

The CFD calculations do not take into account the effects of short-term air supersaturation in airways, though these effects can dramatically change the predicted total and regional particle deposition.

Thus, current CFD calculations on air pollution exposure and inhalation toxicology can have an unusually significant software bug.

Introduction

Particle condensation growth and surface deposition in the adult nasal airway under four psychrometric inhalation conditions for initially 200nm particles

Highlights

1. Cold, rainy or wet weather can induce supersaturated conditions in airways
2. Supersaturation can lead to enhanced deposition of inhaled aerosols
3. Most studies do not consider the possibility of supersaturation in airways

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Methods

Studies published before Oct. 2019 were identified and reviewed using PubMed, Google/Google Scholar, ScienceDirect and Web of Science. The eligible studies included those describing aerosol deposition in the human respiratory tract, enhanced condensational growth applied to respiratory delivery, supersaturation and condensational growth in airways, inhalation toxicology, respiratory drug delivery, processes of deposition of particles of different sizes in the airways, and processes of heat and mass transfer in the respiratory tract.

Results

Only 20 studies (Ferron, 1977; 1996; Ferron et al., 1985; 1984-1988; Morrow, 1986; Sarangapani and Weeler, 1996; Sarangapani, 2000; Grasmeijer et al., 2016; Ingelstedt, 1996; Zhang et al., 2006; Longest and Xi, 2008; Longest and Hinde, 2010; Longest et al., 2010; Hinde and Longest, 2010; Kim et al., 2013; Xi et al., 2013; Tian et al., 2011; Xin et al., 2015) were identified which matching the inclusion criteria on supersaturation or oversaturation or condensational growth in the respiratory tract. In all of them, significant aerosol growth was observed.

Conclusion

The primary implication of the results of this conceptual research is that weather patterns can play a significantly more important role in the deposition of ambient submicron aerosols in human airways than previously assumed.

1. tobacco smoke (particle size 140nm-500nm)
2. diesel exhaust emissions (10nm-500nm)
3. fossil fuel combustion (<1000nm)
4. biomass burning (<1000nm)
5. exhaled infectious aerosols produced during normal and tidal breathing(100-400nm)
6. cooking emissions and many others sources

Main Message:

“The possibility of supersaturation is not taken into account in the calculations and estimations of respiratory health hazards connected to submicron aerosols and ESPECIALLY to NON-hygroscopic particles.”

Epidemiology Mystery: “beyond the scope of this POSTER”

Weather and climatic conditions favorable for increased deposition of submicron aerosols (and infectious aerosols) in the airways, can be clearly linked to seasons of respiratory infections and an increase in the respiratory symptoms of asthma and chronic obstructive pulmonary disease (COPD).

PS: This conceptual research presents the original concept which synthesizes knowledge from previous studies and presents it in a new context to bridge existing theories in new ways. Links work across disciplines, provide multi-level insights to allow safe moving beyond the current norm will enhance knowledge.