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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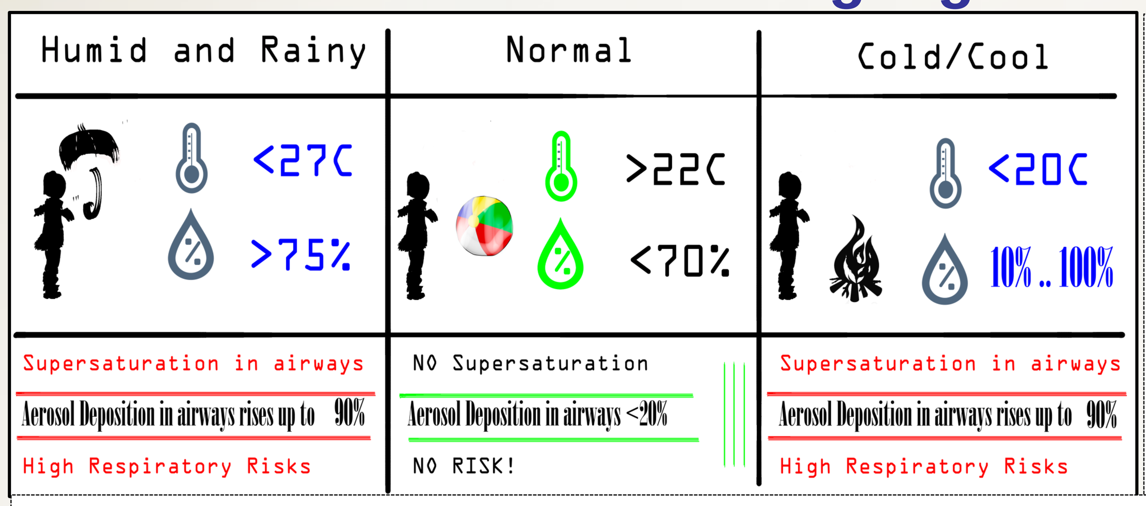
Highlights



Capsule: While few studies have directly shown that supersaturated conditions in airways lead to enhanced aerosol deposition, practically no one takes into account the role of weather patterns in inducing supersaturation in airways.

1 Cold, rainy or wet weather can induce supersaturated conditions in airways

2 Supersaturation can lead to enhanced deposition of inhaled ambient aerosols

3 Most studies do not consider the possibility of supersaturation in airways

Introduction

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

Reprinted from: (Xi et al., 2015) Heat Transfer and Fluid Flow in Biological Processes / editors: Sid Becker and Andrey Kuznetsov /chapter 5: Characterizing Respiratory Airflow and Aerosol Condensational Growth in Children and Adults Using an Imaging-CFD Approach, by Jinxiang Xi, Xiuhua A.Si and Jong, , W.K., P.125-155, Copyright (27 may 2019: License Number: 4597091044115), with permission from Elsevier.

<u>“Supersaturation and Enhanced Condensational Growth in pulmanary drug delivery strategy”</u>

<u>**Here it was hypothesized**</u> that some specific weather conditions (such as a decrease in air temperature) could provoke air supersaturation in human airways, potentially leading to enhanced deposition of ambient submicron aerosols in the respiratory tract. The effect would be similar to the deposition of submicron drug particles under supersaturated conditions in the pulmonary drug delivery strategy.

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 drug 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

WHEN?

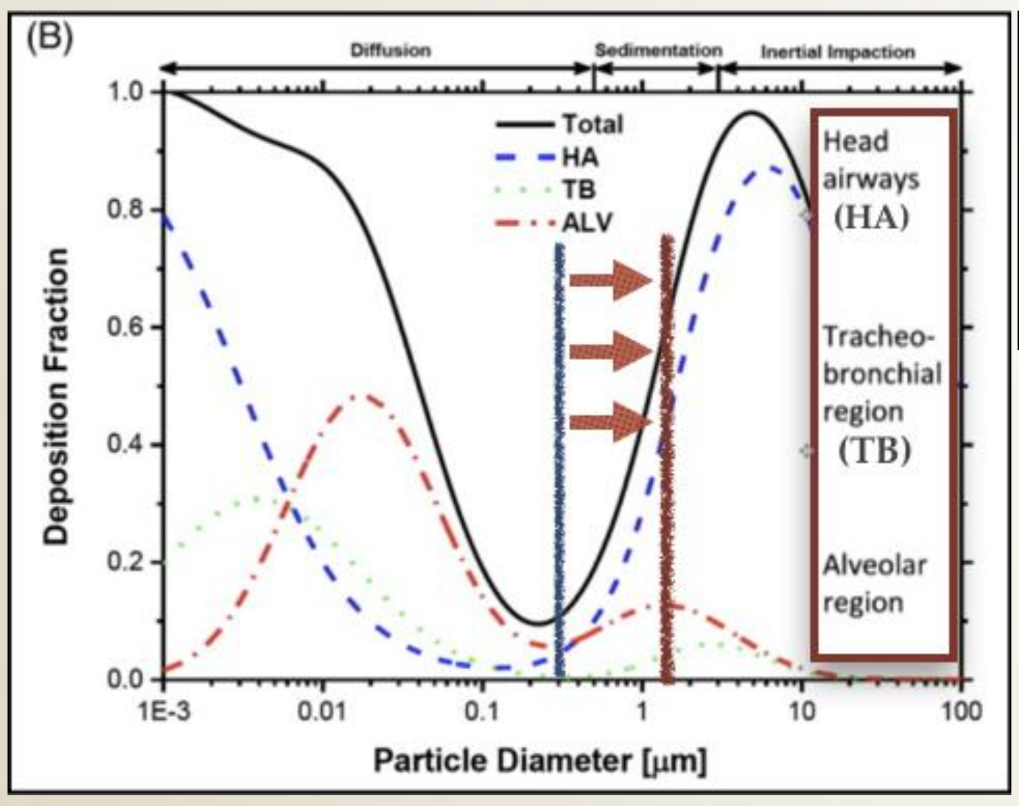
Inhaled air T,°C	RH	Maximum of RH(%) in the airways	Growth factor (change of particle size)	Ref.
47°C	100%	>=101%	**up to 17.5** (hydrosc. partic. 0.2μm)	Xi et al., 2015
20°C	60%	<100%	no effect	Ferron et al., 1984; Longest et al., 2011; Jinxiang, 2015; Golshahi et al., 2013; Winkler-Heil, 2014
22°C	97.5%	101%	**2.5** (for hydroscopic particle of 0.9 μm)	Longest, 2011
20°C	100%	102%	**4** (for dry NaCl particle of 0.3 μm)	Ferron, 1984
10°C	80%	104%		Zhang et al., 2006
10°C	50%	105%	**5** (for NaCl particle of 0.3 μm)	Ferron, 1984
0°C	50%	125%	**20** and **8** (NaCl particle of 0.1μm and 0.3μm)	Ferron, 1984

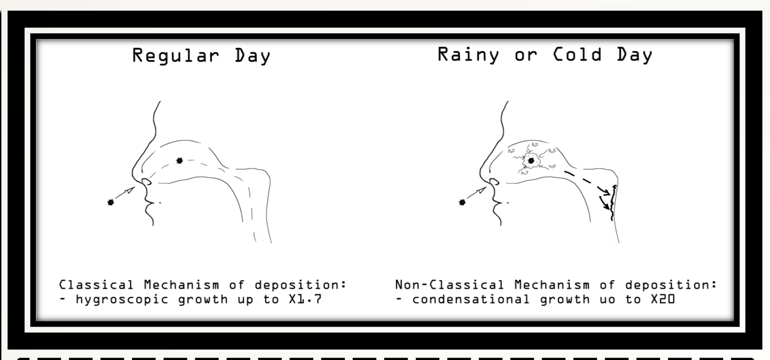
Scan me

FULL VERSION OF TABLE SEE IN

Only 20 studies (Ferron, 1977; 1996; Ferron et al., 1985; 1984; 1988; Morrow, 1986; Sarangapani and Wexler, 1996; Sarangapani, 2000; Grasmeijer et al., 2016; Ingelstedt, 1956; Zhang et al., 2006; Longest and Xi, 2008; Longest and Hindle, 2010; Longest et al., 2010; Hindle and Longest, 2010; Kim et al., 2013; Xi et al., 2013; Tian et al., 2011; 2014; Xi 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.

What does it mean?





<u>The pattern of deposition of submicron aerosols in the airways can be dramatically changed due to supersaturation and enhanced condensational growth</u>

Reprinted from // Janine Fröhlich-Nowoisky, et al Earth system: Climate, health, and ecosystem interactions, Atmospheric Research, V182, 15Dec2016, P346-376, ISSN 0169-8095 (http://www.sciencedirect.com/science/article/pii/S0169809516301995)

How 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 oversaturation 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.

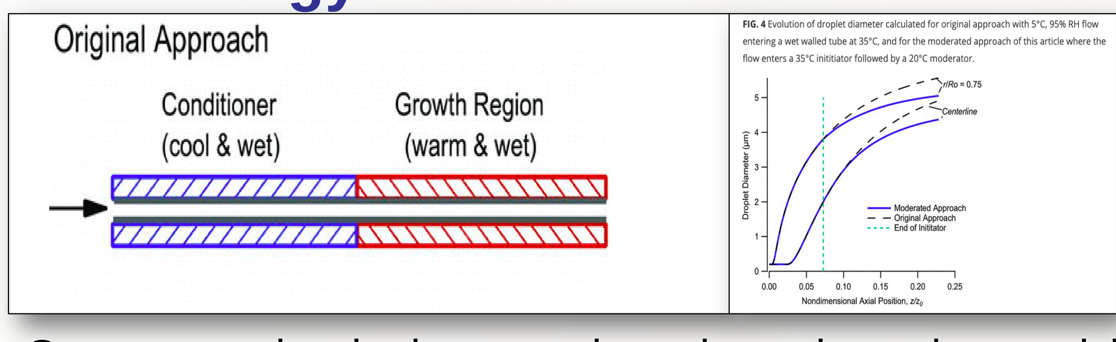
For reference, the problem with the classical view of the deposition of ambient aerosols in human airways is that it is based on the postulate that under any weather conditions, the conditions in human airways will be normal (RH=90%-99.5%; T=30˚C-37˚C) (see the related review in (Elad et al., 2008)). Under such “classical/normal” conditions in the airways, the hygroscopic and condensational growth of inhaled particles is limited by a <u>**growth factor of 1.3-1.7**</u> (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 (***<u>growth factor of more than 10-20</u>***).

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.

Analogy to water-based condensation "growth tubes"



wall temperatures of growth region/tube 29°C-40°C.

airflow at 0°C and 5°C entering in growth region

Supersaturation in the water-based condensation particle counters that are used for environmental monitoring of ultrafine particles. The method used in particle counters involves the introduction of a cool air flow with ultrafine particles into a warm wet-walled “growth tube”. In such conditions, the particles act as condensation nuclei and supersaturated vapor condenses onto these particles to form larger, easily detectable droplets (Hering and Stolzenburg, 2005).

What types of particles are detectable (indicating enhanced growth by condensation)**:** *<u>Hygroscopic and Non-Hygroscopic particles</u>* of sub-10 nm sizes (**non-hygroscopic oil (oleic acid)** and particles from **diesel-dominated vehicle emissions** in the experiments with wet-walled “growth tube” were used by Hering et al (2005)!

if we accept the assumption that under specific conditions (for example, cold air inhalation) the human airways (**wall temperature of 37ºC and RH of near 100%)** can serve like a warm, wet-walled “growth tube”, we can reach an interesting conclusion for the first time in history. That is,

<u>Ultrafine</u> **(particle size below 100nm), and *<u>submicron</u>* (particle size below 1μm), and fine (particle size above 1μm) hygroscopic and NON-HYGROSCOPIC particles will grow in size due to enhanced condensational growth under supersaturated conditions in the upper airways.**

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 (30nm–500nm) ;
3 fossil fuel combustion (<1000nm) ;
4 biomass burning (<1000nm) ;
5 exhaled infectious aerosols produced during normal and tidal breathing(100-400nm)
.. cooking emissions and many others sources

!!!!ENHANCED Deposition of NON-HYGROSCOPIC aerosols

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. “

<u>“Epidemiology Mystery”</u>-***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, provides multi-level insights to show how moving beyond the current norm will enhance knowledge.”

I report no competing interests. The study was conducted without the involvement of any funding sources.