PHYSICAL CAUSES OF FINE DUST AND ITS EFFECTS ON HUMAN LUNGS

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Introduction

Nanoparticles penetrate the lungs in a huge amount every breath we take. Especially in combustion processes a large amount of harmful Nanoparticles is produced, which mix together with the ambient air in the environment. Therefore it is of importance for our health to investigate these processes. In this paper a three stage similarity proof - based on Fick's law of diffusion applied for particle coagulation - is given showing the health relevancy of the number concentration of Nanoparticles versus the mass concentration.

Deposition in the lungs

The preliminaries are that the deposition of PM10 is happening late in the bronchial tree of the human lungs, branching because of its fractal nature. The air velocity and the diameter of the air tubes are getting smaller and smaller in direction to the alveoli (v~d) [1]. Minimal air resistance and a big particle residence time leads to **diffusion deposition**. This means that particles travel deep into the lungs and that they have a long residence time there.

Compared to the diffusion deposition the ELPI (Electrical low pressure Impactor), which functions according to the principle of the **inertia deposition**, separates the smallest particles from approximately 30nm particle diameter with almost speed of sound from the gas stream. Which role plays now this effect of the diffusion separation in the lungs? With diffusion the forces of inertia (mass forces) and thus the mass play a subordinated role.

Similarity proof

The transportation stream of fine dust particles n_p - according to Fick's law (Eq.1) - is proportional to the diffusion coefficient D [2]. For the Stokes-Einstein solution of the diffusion coefficient this means that D is in reverse proportional to the particle diameter d_p ($D \sim 1/d_p$). The diffusion transport $\dot{n}_p$ and thus the deposition probability rise thus for smaller particles still, while the tendency decreases with inertia deposition.

Supposing Eq. 1 [3] a constant geometry of the air tube (d), viscosity and temperature results finally in a diffusion transport (~deposition) proportional to the particle number concentration and inverse proportional to the particle diameter (Eq. 2).

$$\dot{n}_p = \frac{-D}{V_L} \cdot \frac{\partial n_p}{\partial x} \cong \frac{-D \cdot 6}{d^3 \cdot \pi} \cdot \frac{\partial n_p}{\partial x}$$ Eq. 1

$$\rightarrow \dot{n}_p \approx \frac{n_p}{d_p \cdot d^4} \rightarrow \dot{n}_p \approx \frac{n_p}{d_p}$$ Eq. 2

The following consequences result:

- The deposition velocity is supposed to be higher as particles are getting smaller.
- For particles, with the same mass but consisting of smaller particles, the deposition probability increases.
- Related to Eq.2 it can be seen that the same mass divided into several small particles, show a larger impaction (deposition) probability (illustrated in figure 1), as they are smaller and faster.

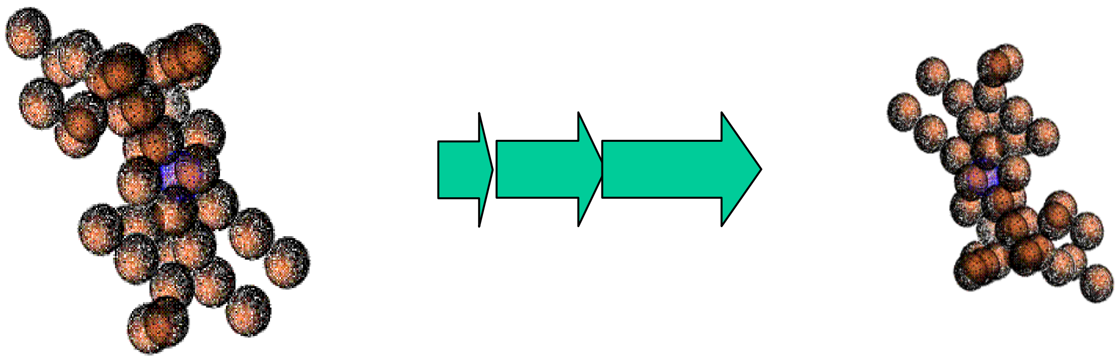

figure 1 *acceleration* of Nanoparticles with decreasing size

Children

Comparing the size scales of the lungs of children and adults an even stronger concern of particle deposition for children is resulting. As their lungs are smaller scaled their physical diameter is smaller. Eq. 2 results when $d_{child} < d_{adult}$ that $\dot{n}_{p,child} > \dot{n}_{p,adult}$. That means that children are stronger concerned than adults. This is especially true for Babys, they are affected by the worst consequences of fine dust.

Conclusion

One mass on the one hand one particle on the other hand divided into several small particles, shows secondly a larger impaction (deposition) probability, because of decreased size and increased velocity.

As a whole it can be concluded for physical reasons that concerning lung health effects the number particle concentration is of decisive interest. This quantity has a greater relevance than the quantity PM10, or mass in general.

Literature

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