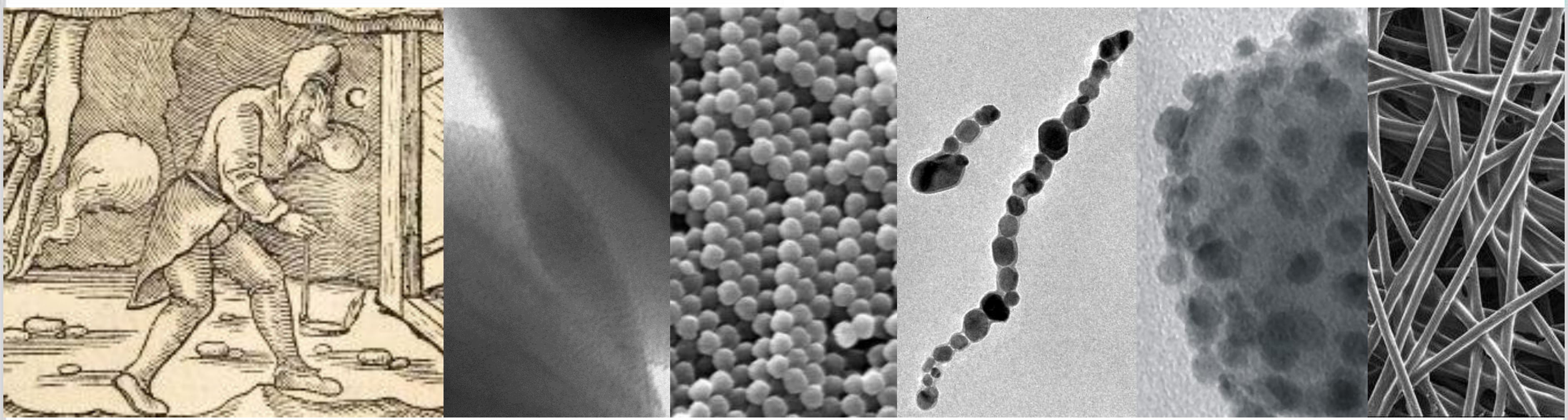
Nanoparticle aerosols in workplace environments

Martin Seipenbusch, KIT, Institute for Mechanical Process Engineering and Mechanics



Outline

- Introduction
- Sources for Nanoparticles in Workplaces
- Changes in Particle characteristics: Aerosol dynamics in workplace atmospheres
- Effect of particle size on deposition efficiency in the lung and protective equipment

Introduction

Particulate nanostructures:

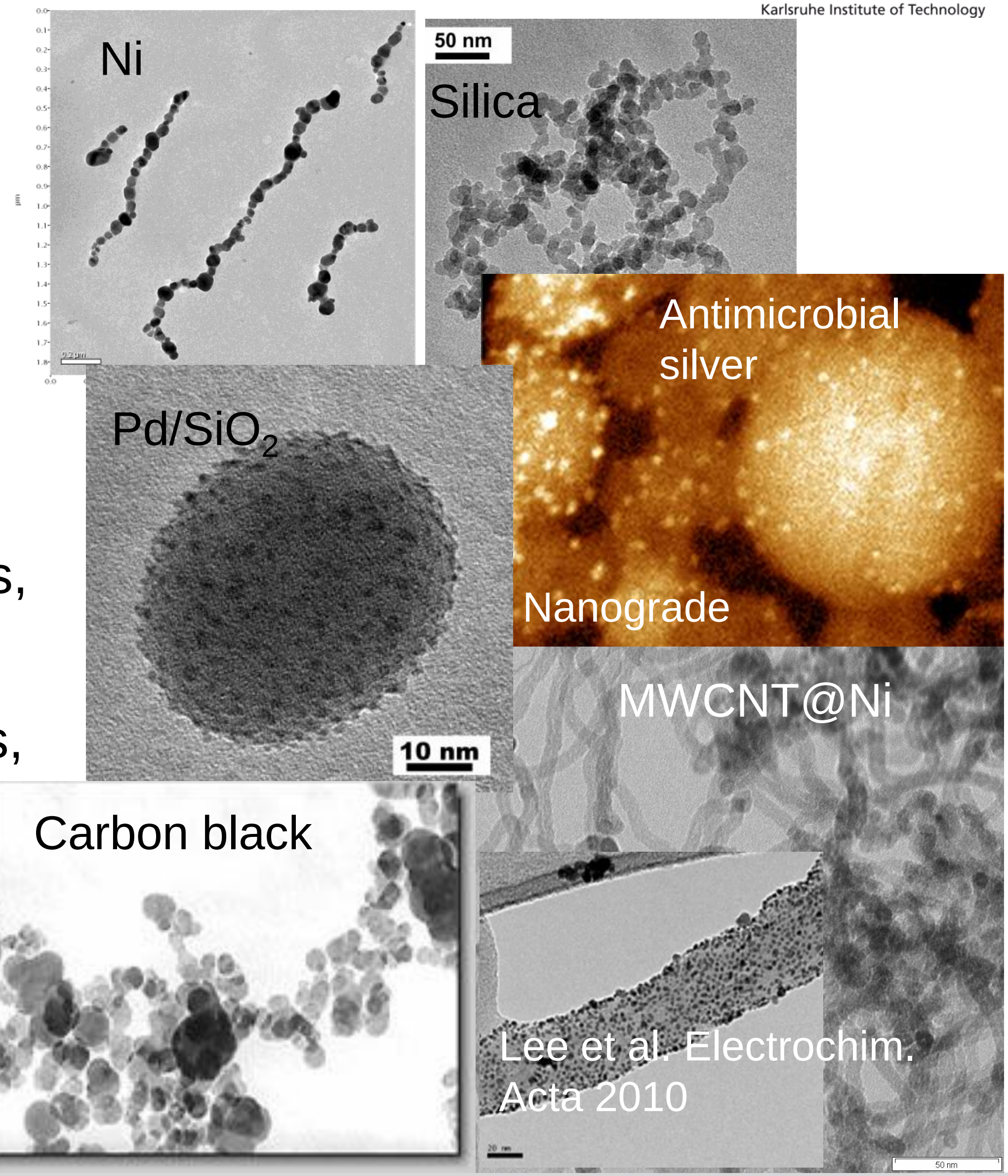
Application areas (examples):

Energy (Solar cells, fuel cells, catalysts e.g. for hydrogen generation)

Mobility (tires, Exhaust catalysts, battery technologies etc.)

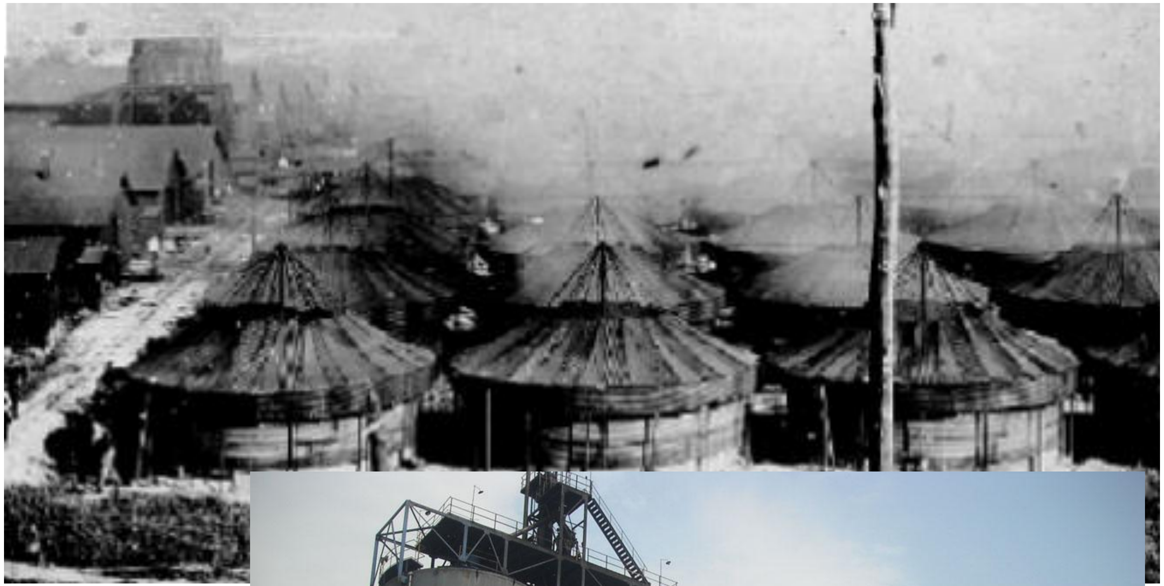
Medicine (antimicrobial coatings, improved biocompatibility of implants)

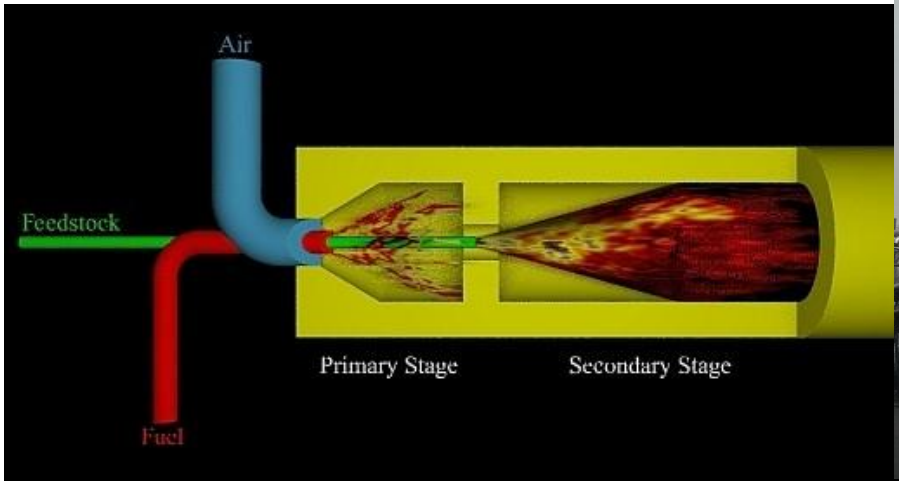
Food industry (thickening and flowability agents)



Production of Nanoparticles by aerosol processes

- Flame pyrolysis: mass production of comodities (soot, titania, silica, alumina)
- Flame spray pyrolysis
- Plasma processes
- Laser based processes
- …

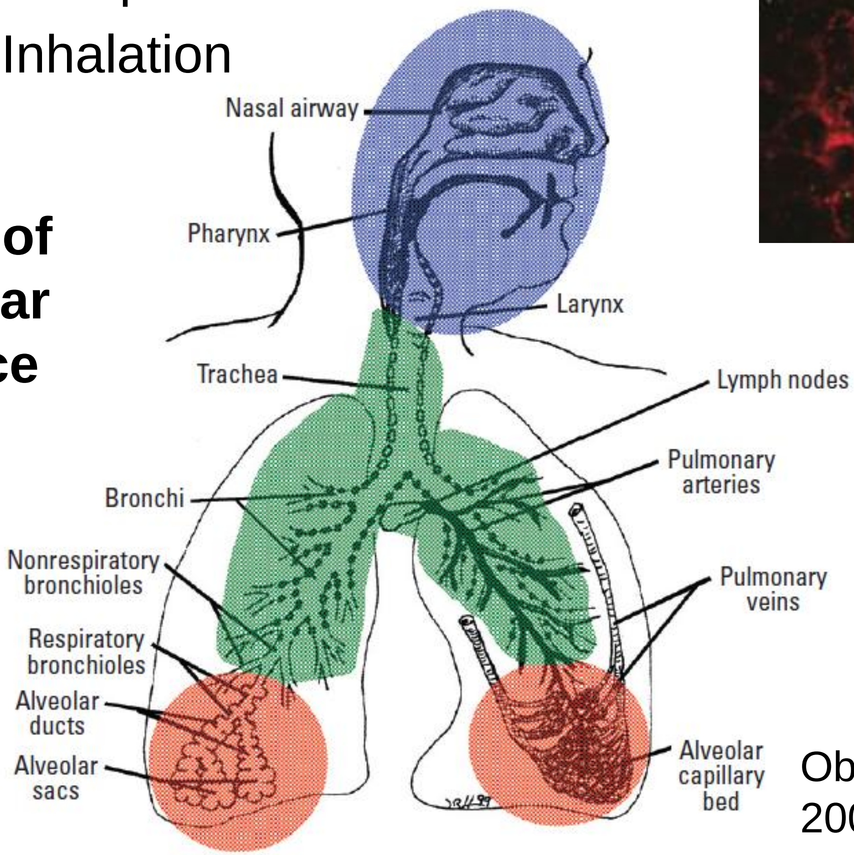




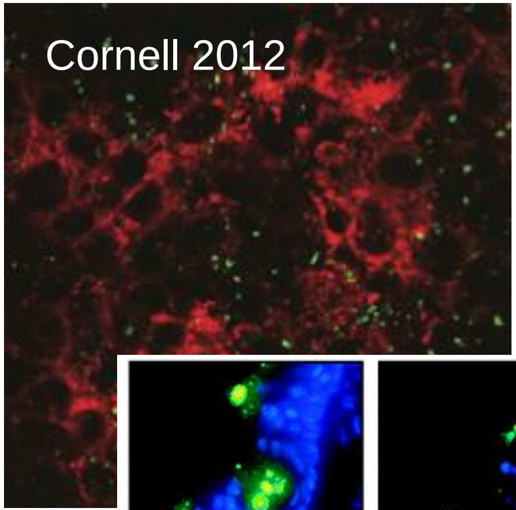
Workplace Exposure with Nanoparticle aerosols

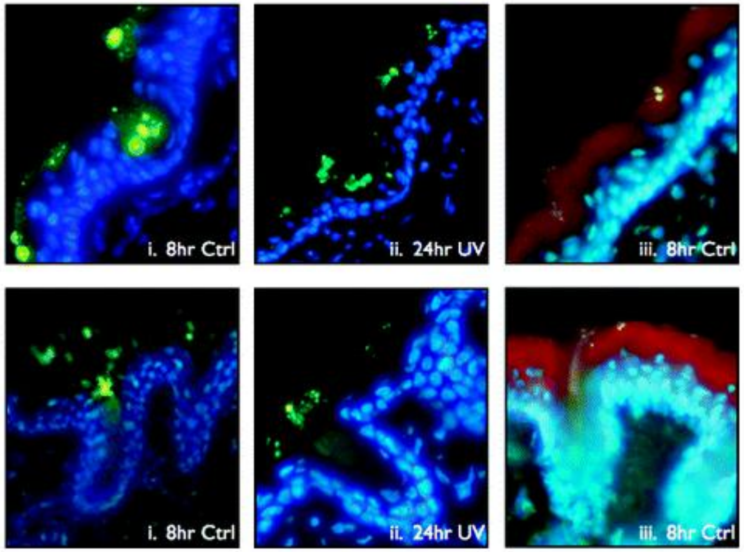
- Possible routes:
  - Ingestion
  - Skin penetration
  - Inhalation

70 m² of alveolar surface



Oberdörster et al. Env. Health Persp. 2003





Mortensen et al Nano Lett 2008

Sources for nanoparticle aerosols in workplaces



Nanoparticle release from industrial processes

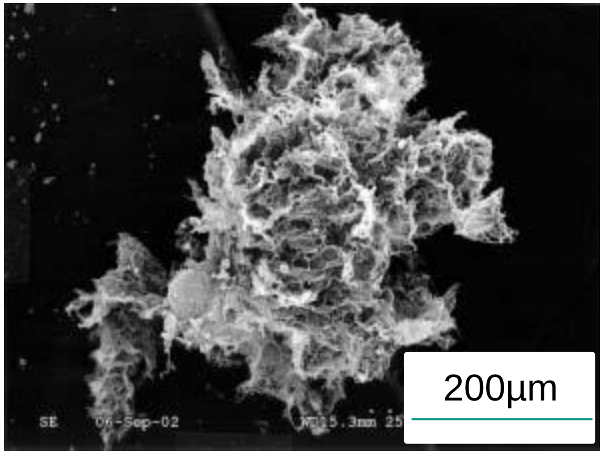
bagging, handling and processing:

Small scale production:

- Workplace measurements for CNT and Silicon-NP: negligible increase in number- and mass concentration (Maynard et al. Tox Envir. Health 2004; Wang et al. J. Nanopart. Res. 2011)

Mass production:

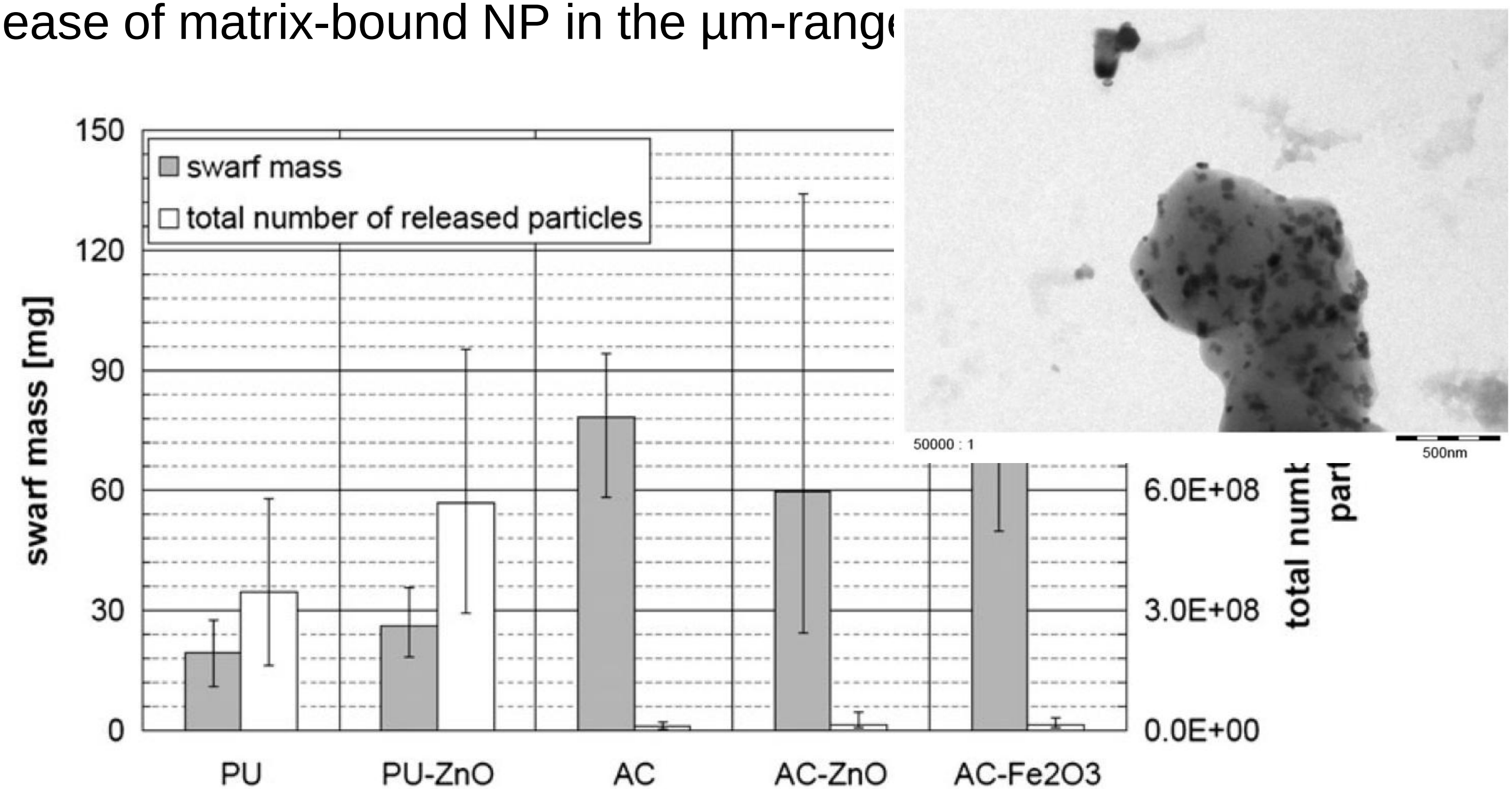
- Bagging of soot: particle mass <10µm (PM_{10}) concentration increased (Kuhlbusch et al. Occ. Envir. Hyg. 2004)



(Maynard et al. Tox Envir. Health 2004)

Nanoparticle release from the use of NP containing products

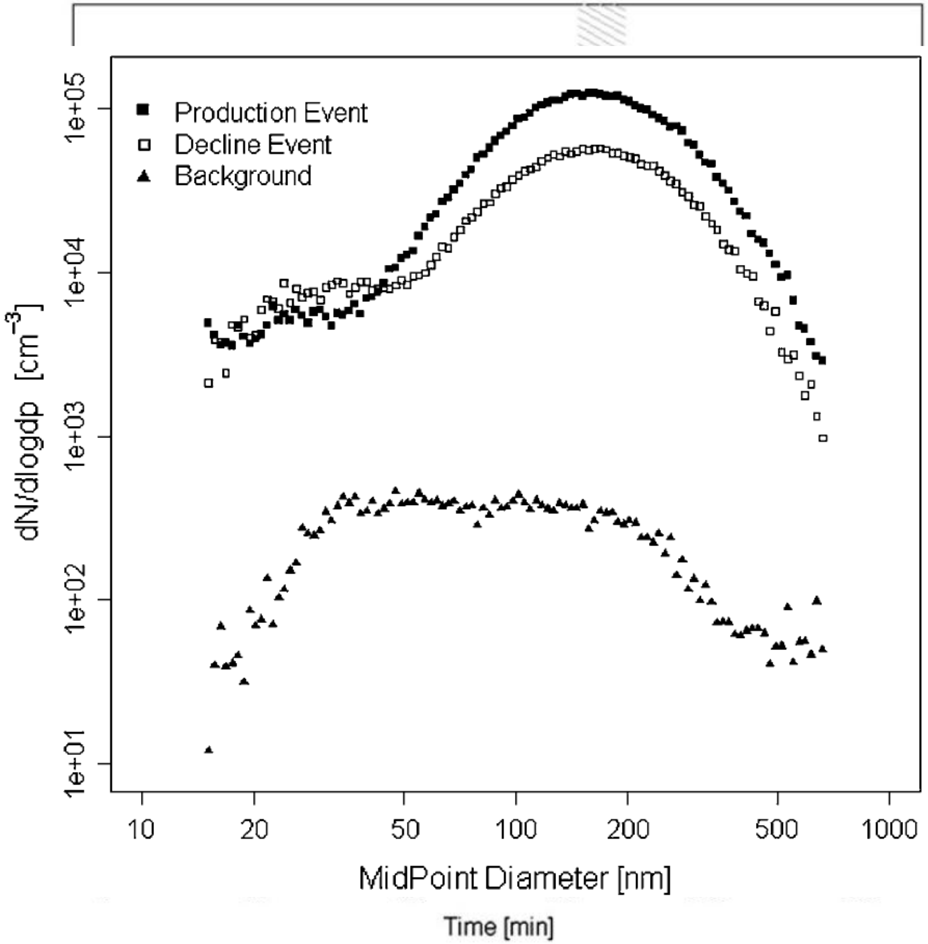
- Sanding and grinding of nanoparticle containing products: release of matrix-bound NP in the µm-range



Göhler et al. Ann. Occ. Hyg. 2010

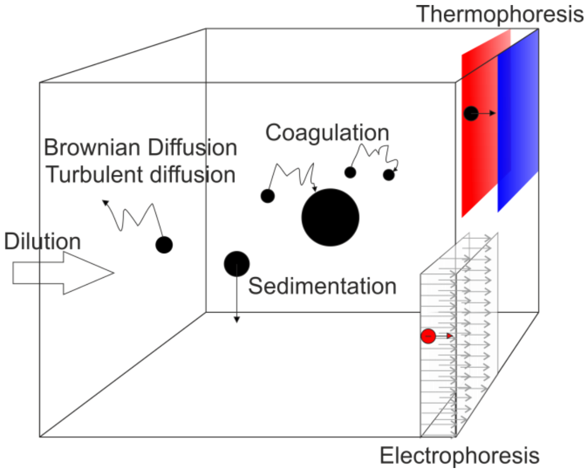
Release of nanoparticles from an open flame reactor

- Release of submicron particles



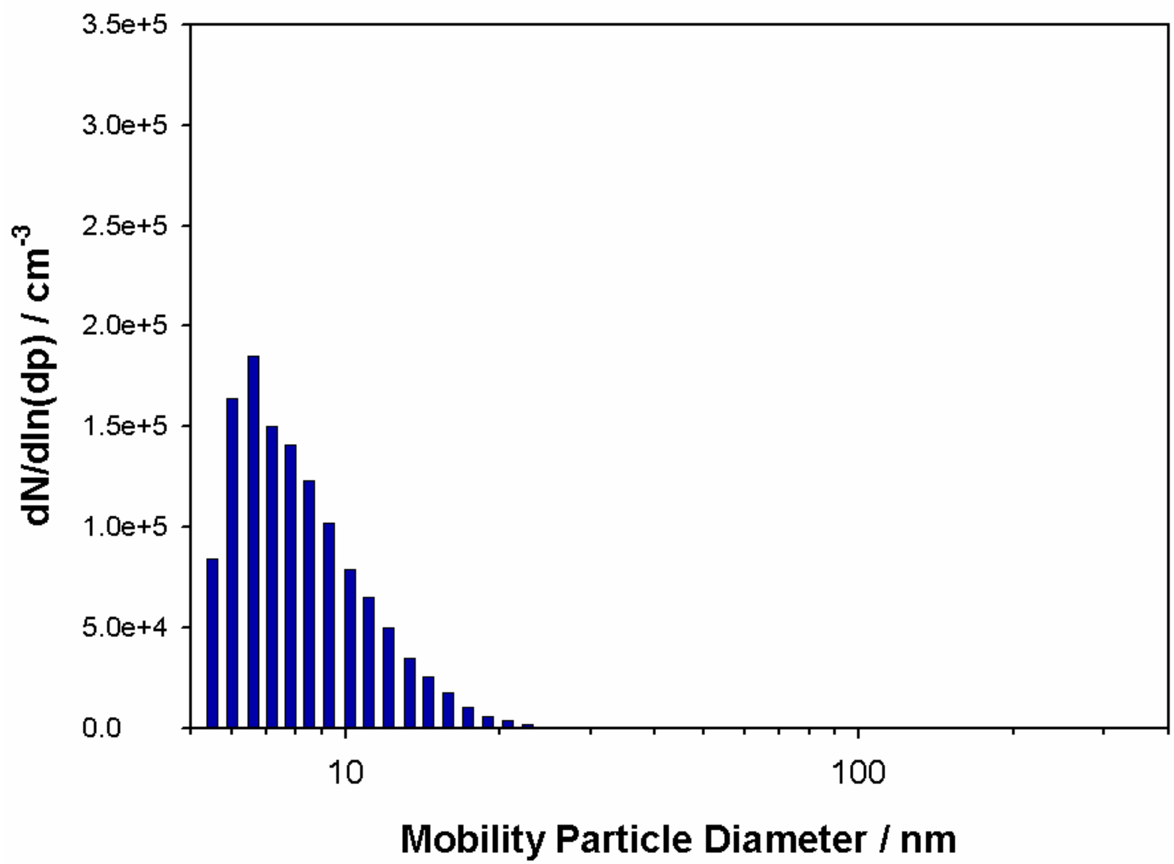
Demou et al. Ann. Occ. Hyg. 2009

Changes in Particle characteristics: Aerosol dynamics in workplace atmospheres

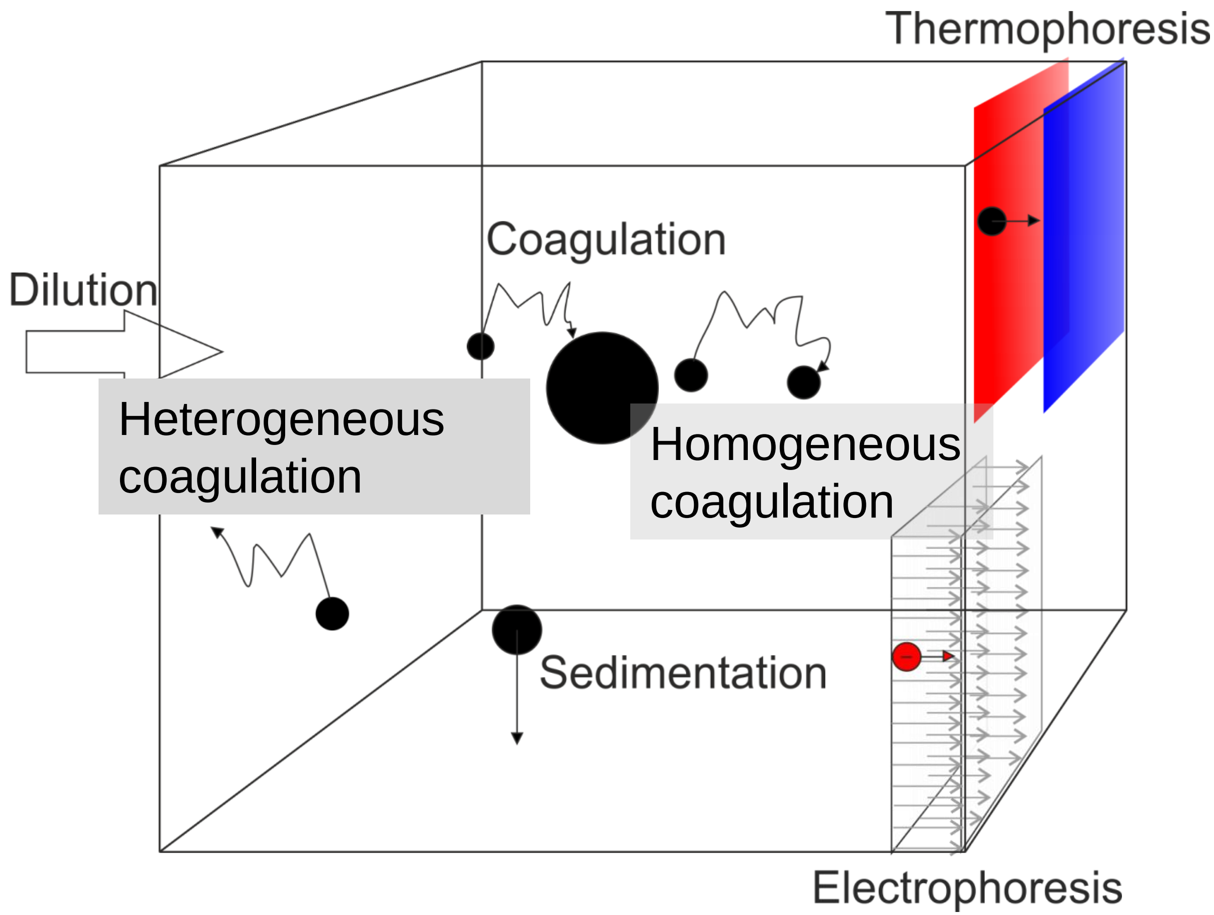


Temporal evolution of a Nanoparticle aerosol

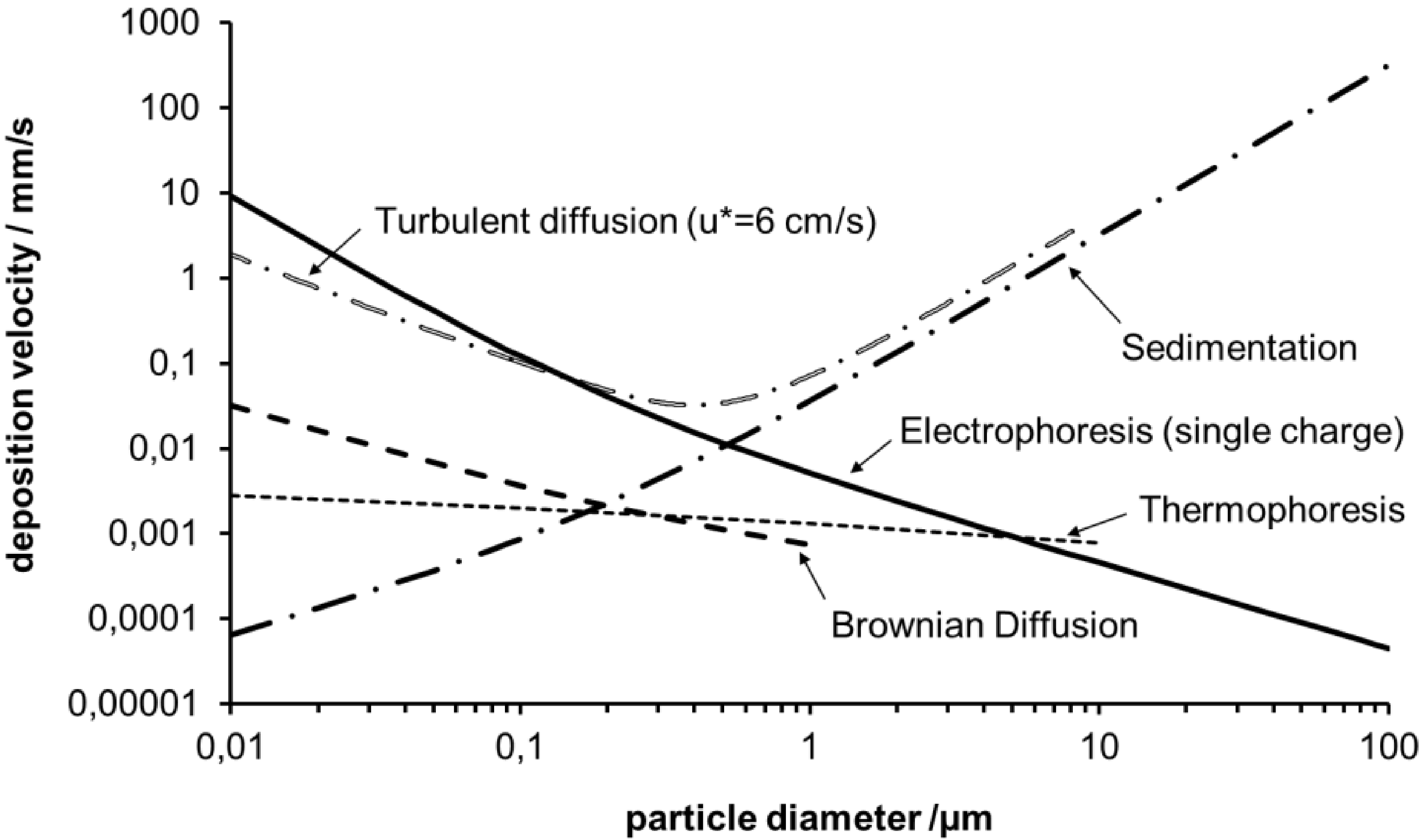
Karlsruhe Institute of Technology



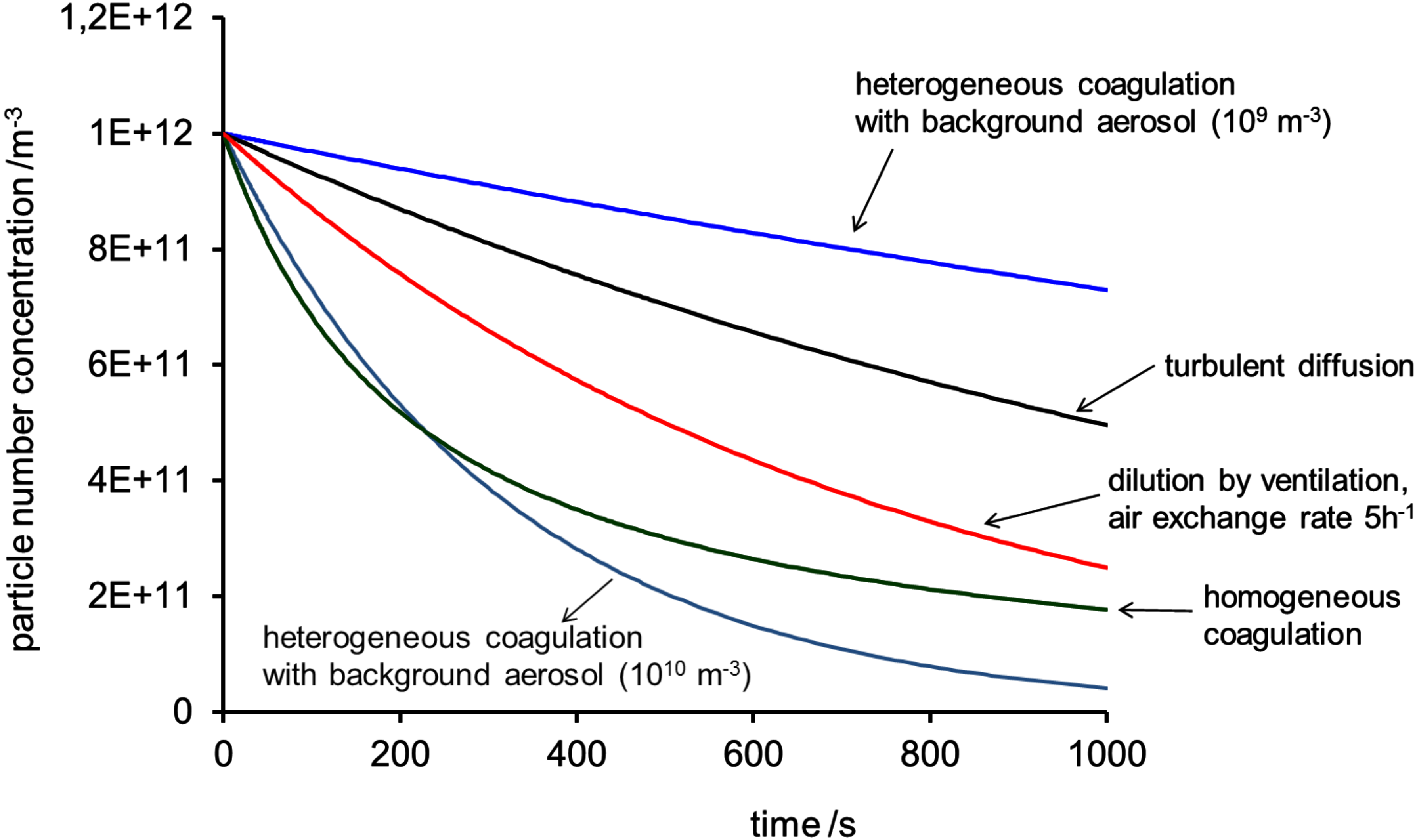
Aerosol dynamics: key mechanisms



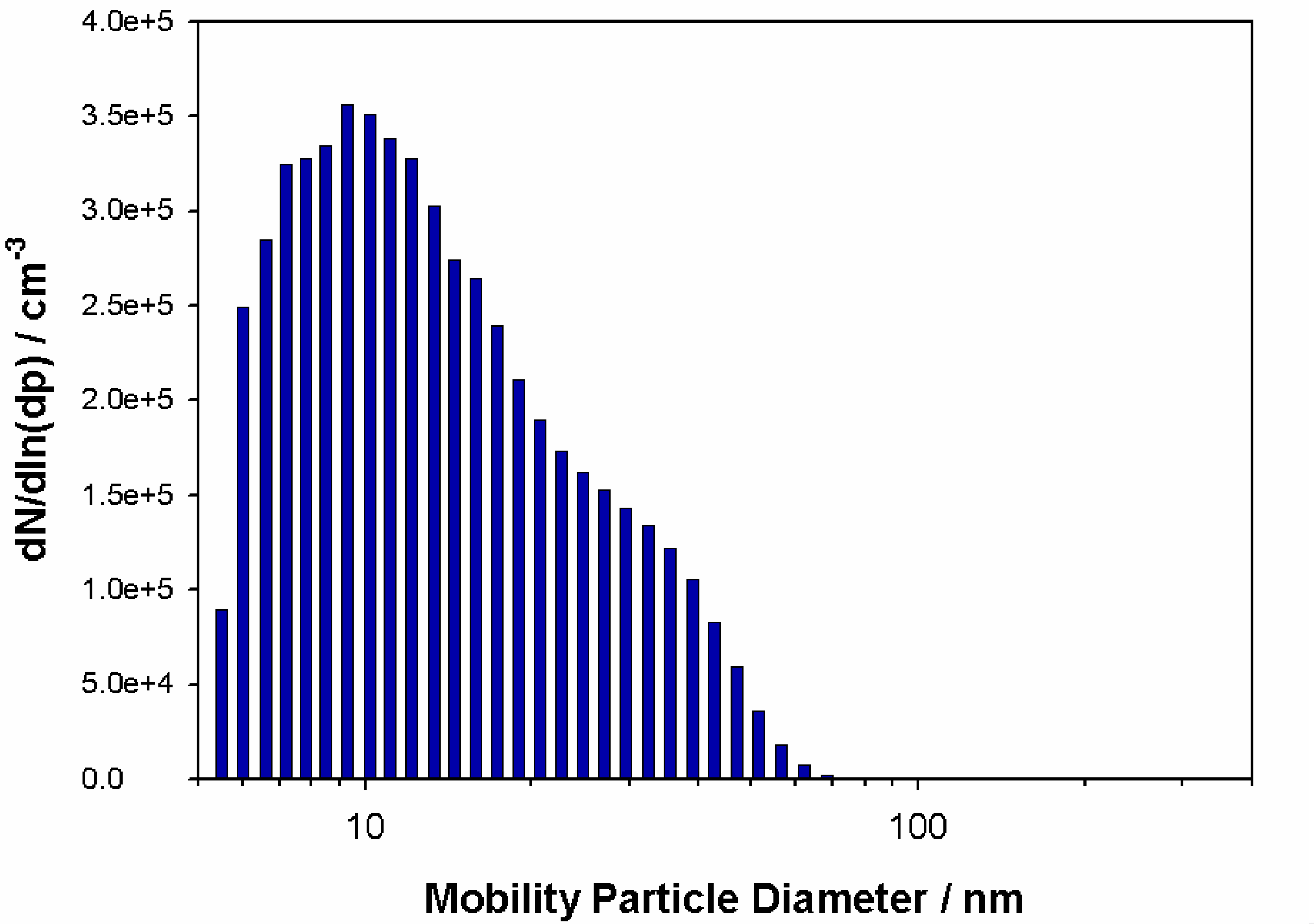
Loss mechanisms: size dependence



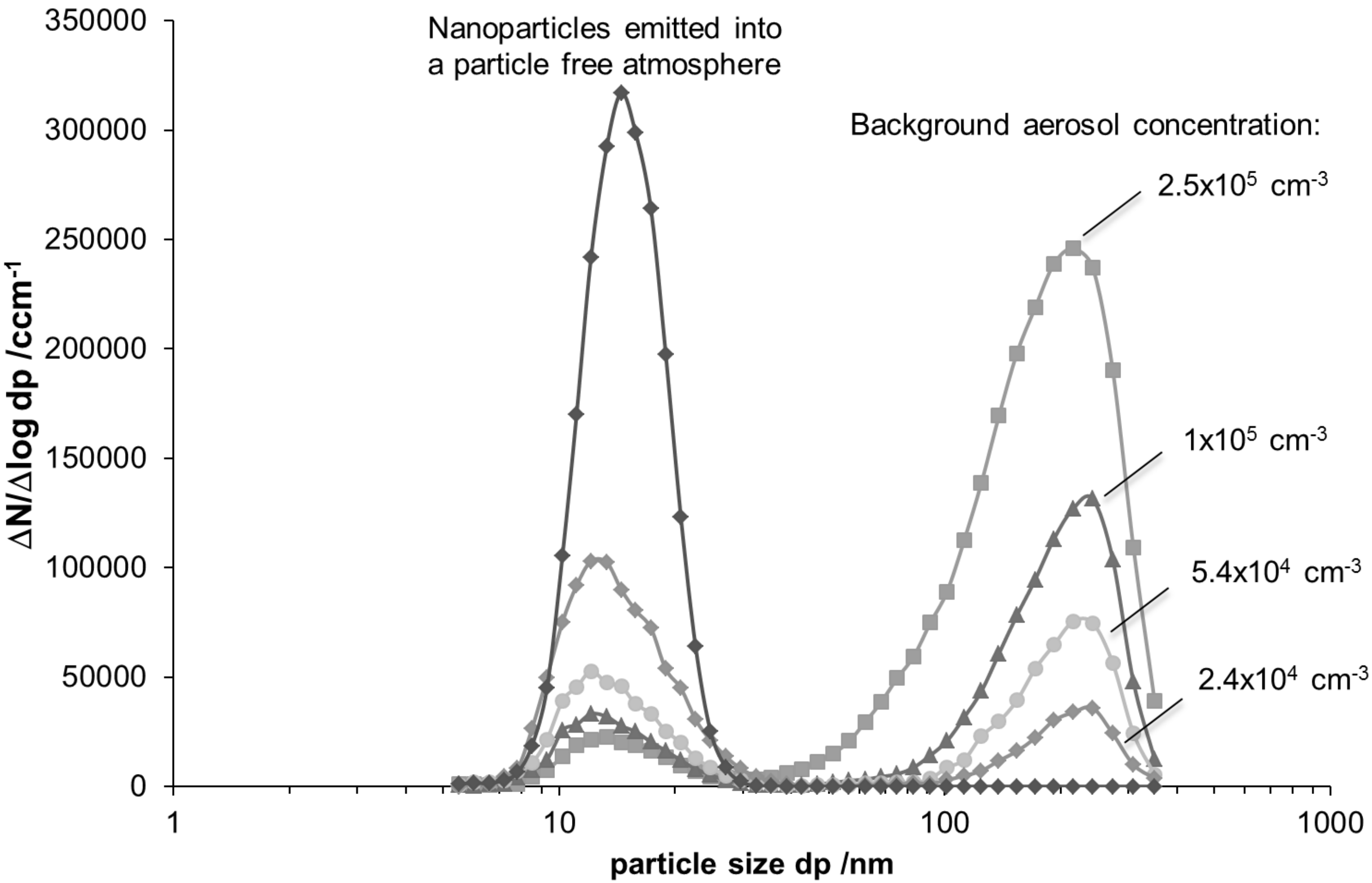
Kinetics of the dominant mechanisms



Polydisperse Coagulation: NP aerosol interacting with a simulated background aerosol

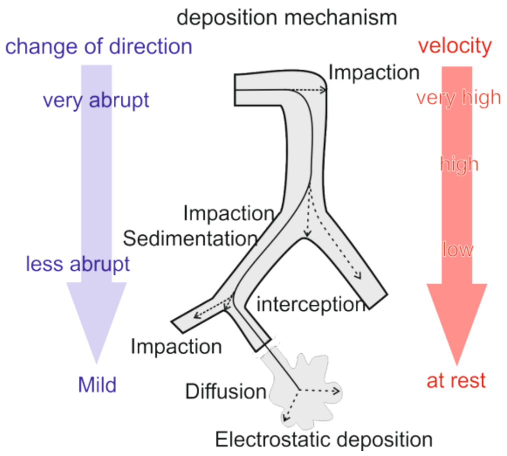


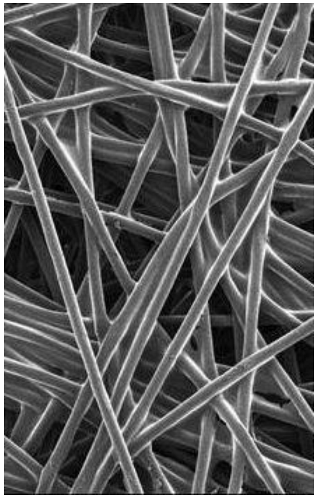
Particle number distributions at steady state (experiment)



Seipenbusch et al. Ann. Occ Hyg. 2009

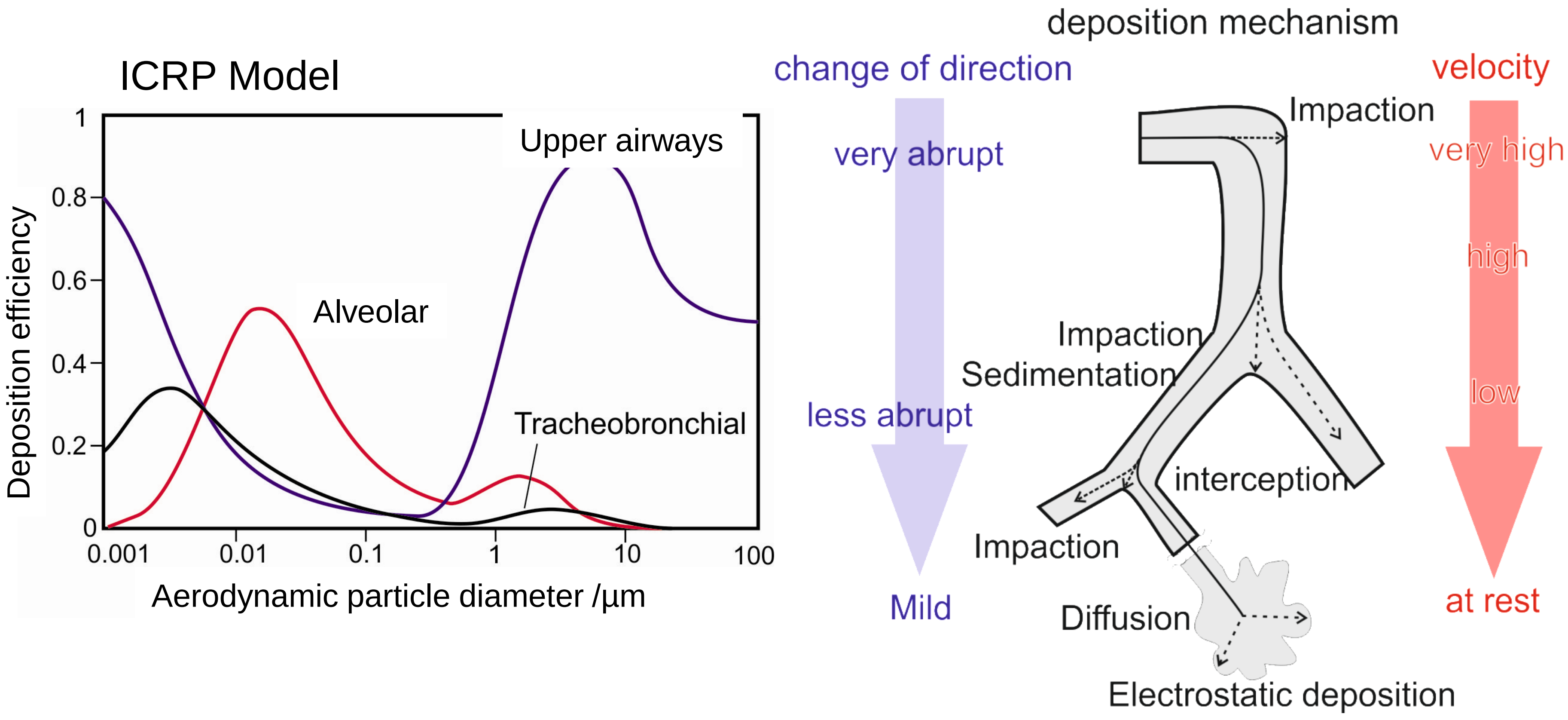
Particle size and deposition in the lung and protective equipment





Particle deposition in the human airways

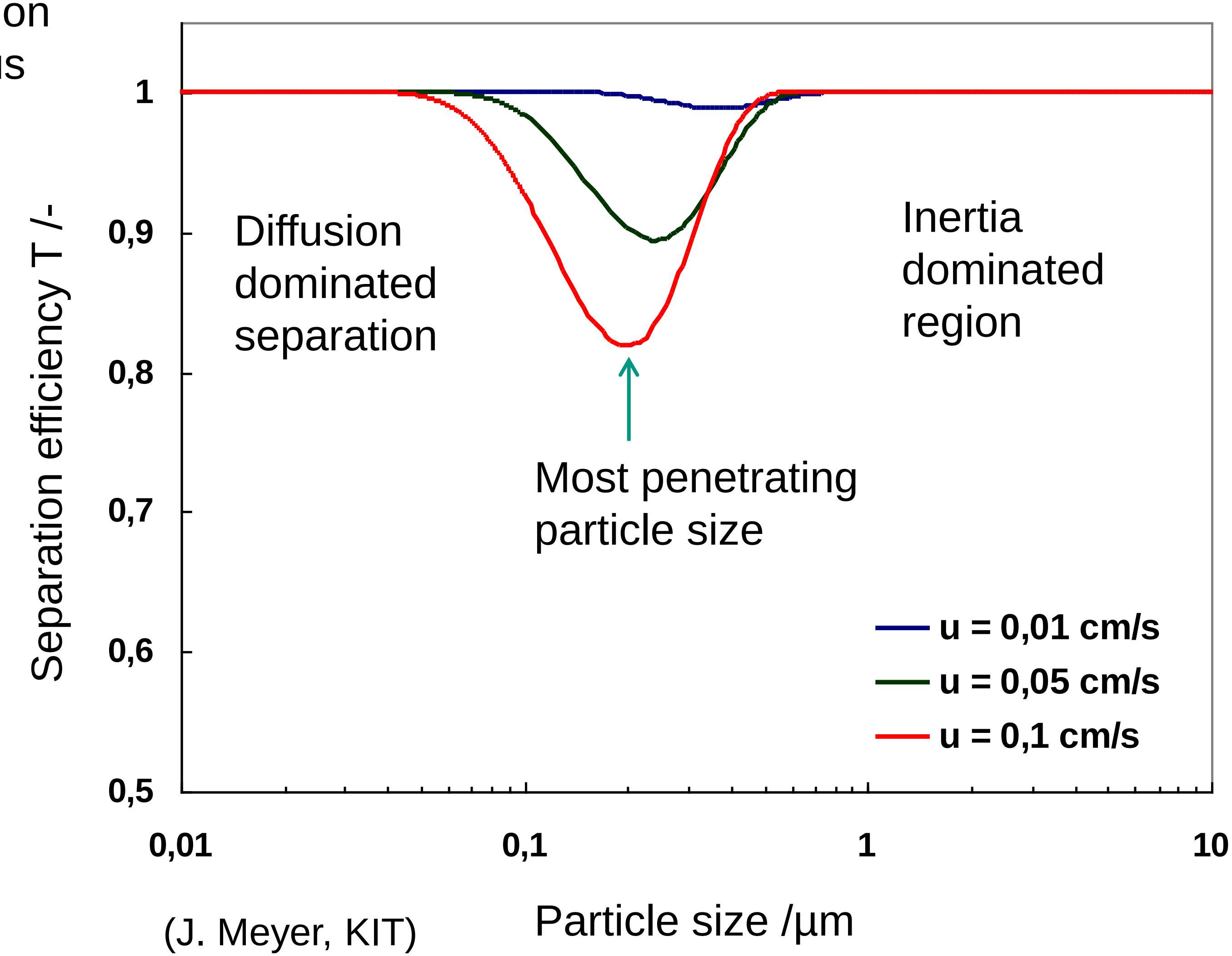
- Aerodynamic behavior decides whether and where particle deposition takes place



(after Bailey Rad. Prot. Dos. 1994)

Deposition of aerosol particles in filters

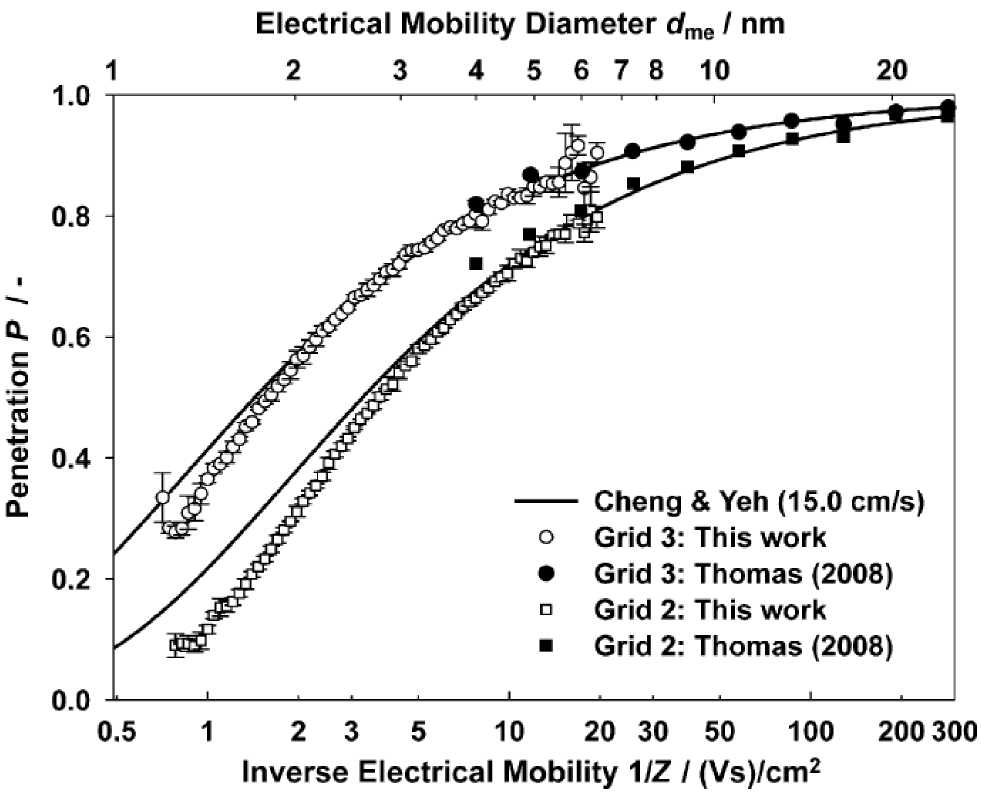
Calculated separation efficiency for various face velocities



(J. Meyer, KIT)

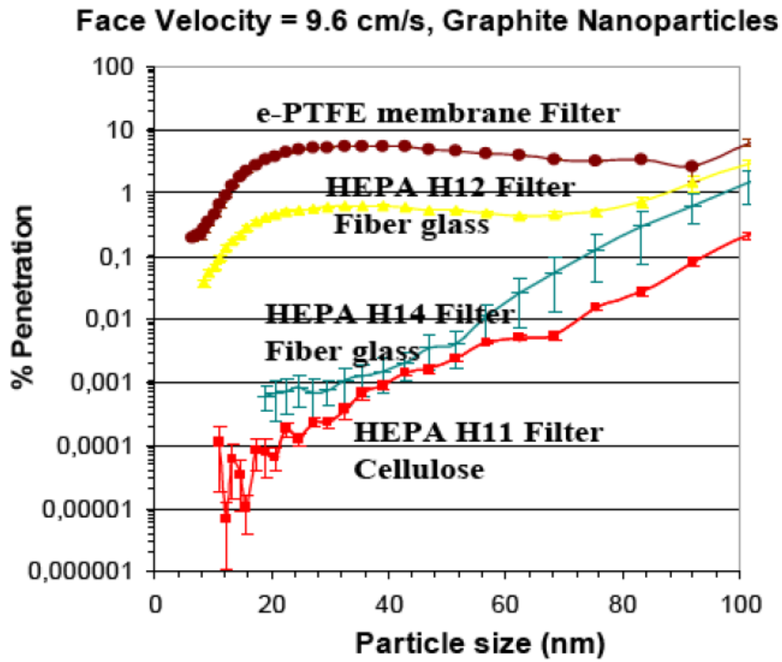
Filter efficiency in the nano-regime

Testing of filtration efficiency on model filters:



(Heim et al. J. Aerosol Sci. 2010)

Tests on real filters:

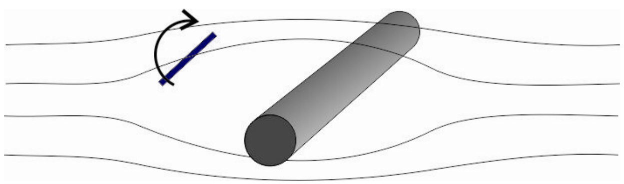


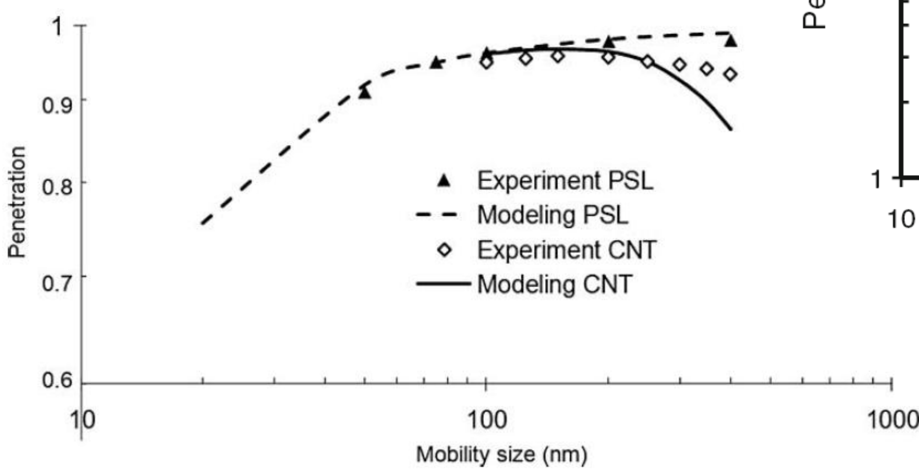
(Nanosafe, diss. report, 2009)

Filter efficiency for non-spherical particles

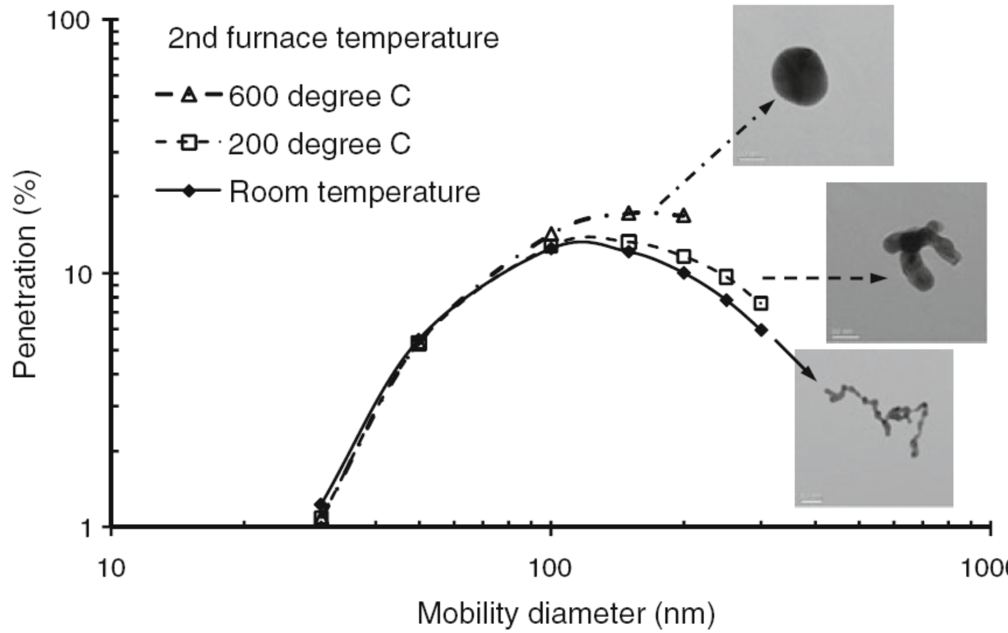
- interception dominates deposition of agglomerates and fibers
- Improved deposition for non-spherical particles

Rotation: random orientation approaching a fiber





(Wang et al. Aerosol Sci. Technol. 2011)



(Wang et al. J. Nanopart. Res. 2011)

Summary

- Sources for Nanoparticles in Workplaces:
  - Most cases: release of highly agglomerated particles
  - For some scenarios free nanoparticles can be found
- Aerosol dynamics in workplace atmospheres:
  - Reduction in number concentration and increase of particle size by several mechanisms, depending on conditions (relevant size range 100-500 nm)
- Effect of particle size on deposition efficiency in the lung and protective equipment:
  - Deposition efficiency in the lung highly dependent on particle size. Alveolar deposition between 1-100 nm
  - Efficiency of protective equipment very high in the nanoregime. MPPS ca. 200 nm