

The Role of Ultrafine Particles in the Atmosphere

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Definition

What is an aerosol?

Aerosol:

→ Solid and/or liquid particles suspended in a gas

Size range of aerosol particles:

→ 1 nm bis 100 μm

Coarse, Fein and Ultrafine Particles

Coarse particles: (coarse mode)

→ Aerosol particles $> 1 \mu\text{m}$

Fine particles: (accumulation mode)

→ Aerosol particles $< 1 \mu\text{m}$ and $> 0.1 \mu\text{m}$

Ultrafine particle: (nucleation and Aitken mode)

→ Aerosol particles $< 0.1 \mu\text{m}$

Sources of Aerosol Particle

There are three different source mechanisms:

1. Bulk-to-Particle Conversion (BPC)

→ New particles produced from bulk material

2. Gas-to-Particle Conversion (GPC)

→ New particle number or mass produced from condensable gases

3. Combustion

→ Emission of new particles or condensable gases

Coarse Particles

Coarse particles are mainly produced by BPC processes:

- BPC: dispersion, erosions, re-suspension
- Compounds: e.g. sea salt ,mineral dust, pollen, bacteria
- Live time is hours to days
- Cloud condensation nuclei
- Scatter and absorb solar light
- Removed by sedimentation, rain and wash out
- Significant subfraction of the aerosol mass

Fine Particles

Fine particles are mainly originated from GCP and combustion processes:

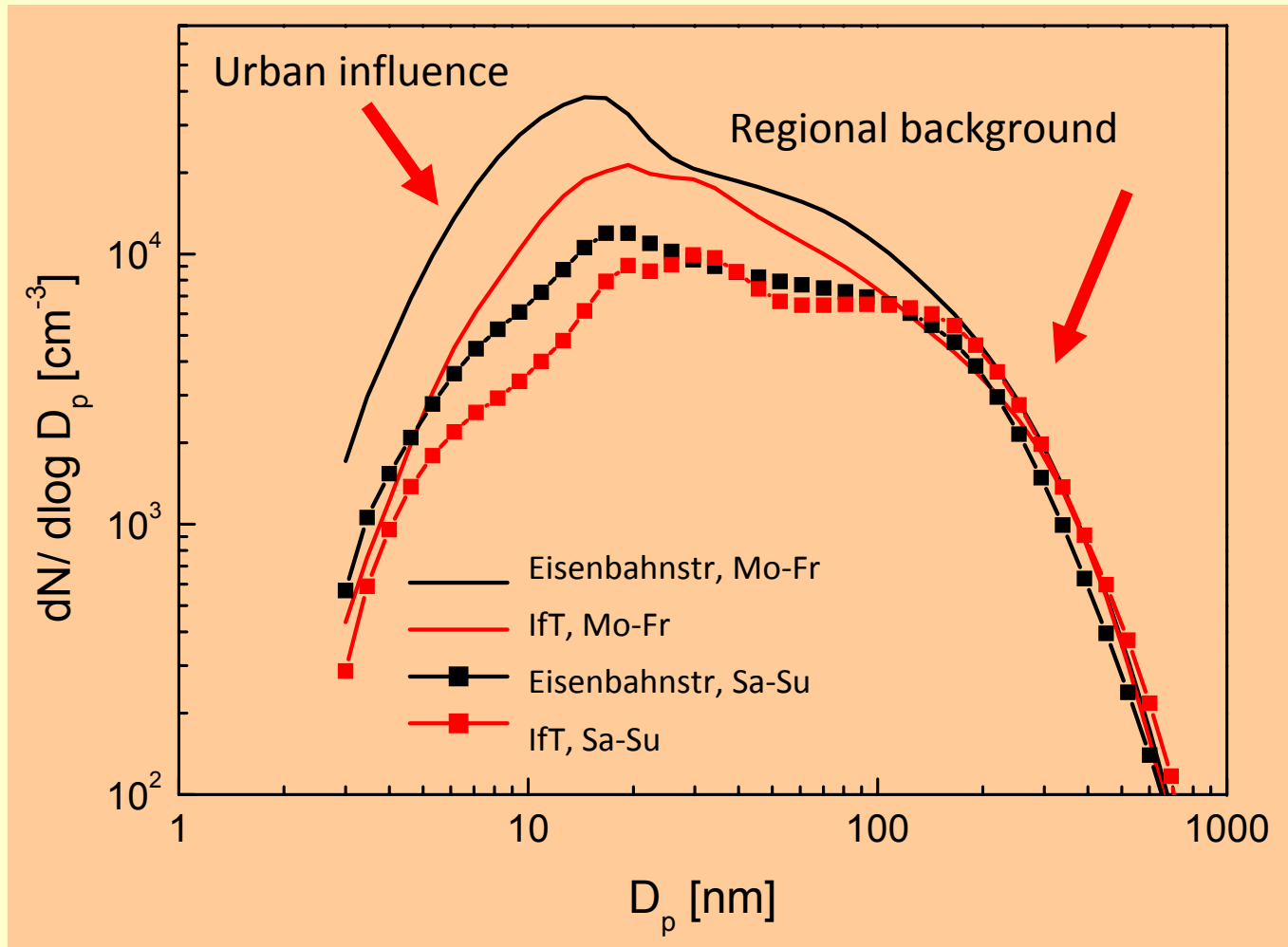
- GCP: condensation, coagulation, and liquid phase chemical reactions in clouds
- Compounds: sulfate, nitrate, ammonium, organic and elemental carbon
- Live time is days to weeks → regional background
- Cloud condensation nuclei
- Scatter and absorb solar light
- Removed by rain and wash out
- Often main fraction of total aerosol mass

Ultrafine Particles

Ultrafine particles are produced either by GCP or combustion processes:

- GCP: Homogeneous nucleation of condensable gases
- Combustion: emission of soot particles (precursor gases)
- Composition: Sulfate, nitrate, ammonium, organic carbon, elemental carbon
- Live time is hours to days → local aerosol
- Removed either by coagulation or diffusion to surfaces
- Minor fraction of total aerosol mass

Urban Number Size Distribution



Number and Mass Concentration

	Number 3 -100nm (#/cm ³)	Number 3 -800nm (#/cm ³)	Mass 3 -100nm (µg/m ³)	Mass 3 -800nm (µg/m ³)
IfT, Mo-Fr	17500	19800	1,3	26,9
IfT, Sa-Su	8300	10900	0,9	30,8
Eiba, Mo-Fr	29900	32900	1,9	28,9
Eiba , Sa-Su	10600	12900	1,0	27,0

Homogeneous Nucleation

There are two different kind of processes for homogeneous nucleation:

1. Photochemical production of condensable gases from precursors

These nucleation process is usually regional

2. Emissions of condensable gases from high temperature combustion

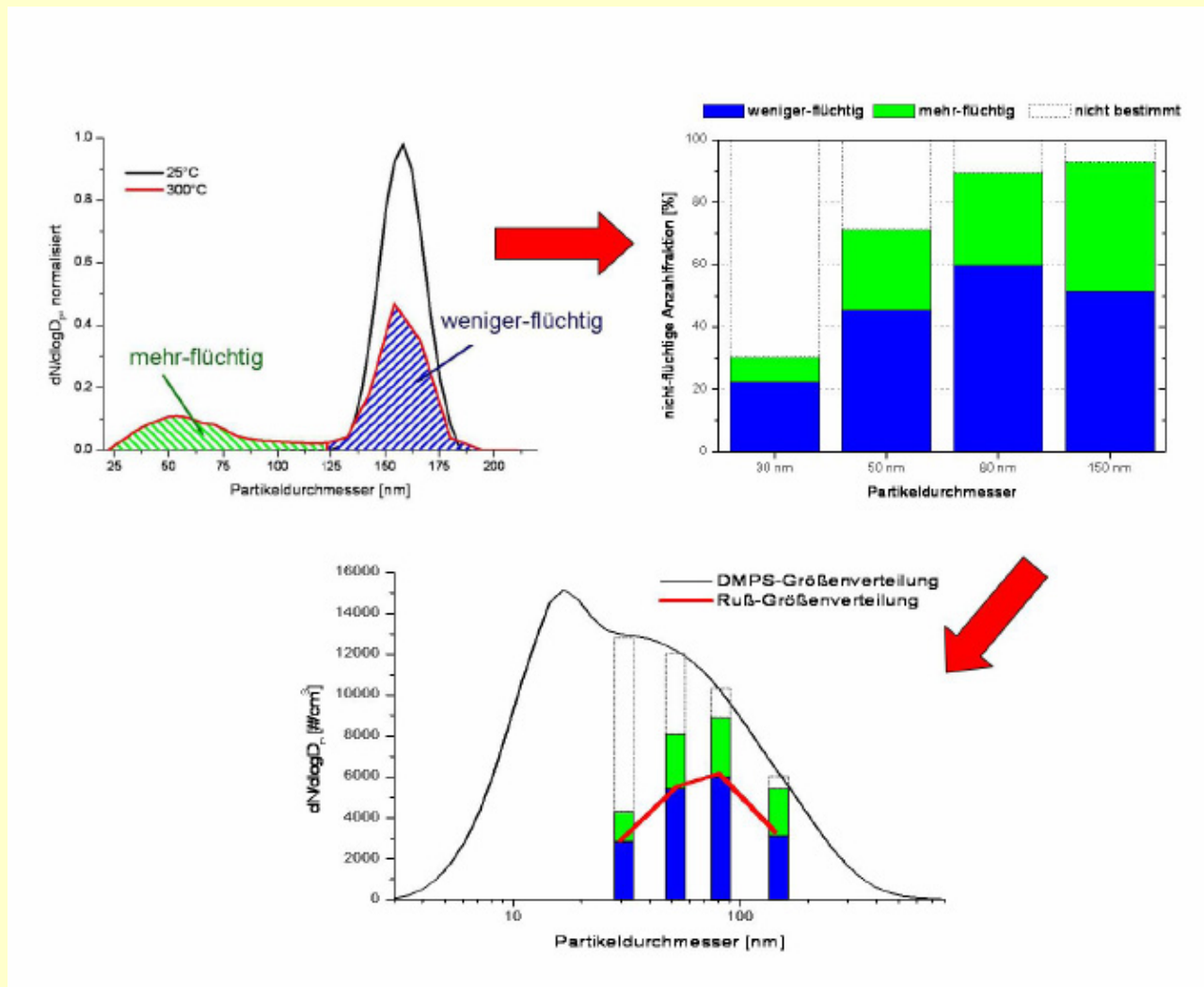
This nucleation is observed in urban environments or close to motorways

Vehicle Emissions

Diesel-driven vehicles emit soot particles:

- Modern diesel-cars emit number-wise mainly ultrafine soot particles
- The mean number diameter lies from 50-70 nm
- The mean mass diameter is around 300 nm
- Soot contains mainly elemental carbon
- Organic carbons such PAHs are adsorbed to the particles
- Fresh soot particles might be surface reactive

Soot number distribution in a street canyon



Are ultrafine particles relevant for the climate?

Continuous source to maintain the particle number concentration in the atmosphere

→ Due to homogeneous nucleation and combustion

Cloud formation and light scattering

→ Due to growth of ultrafine particles into the accumulation mode range ($> 0.1 \mu\text{m}$)

Light Absorption

→ By soot particles

Are (Ultra)-Fine Particles Dangerous?

An increased aerosol mass concentration is generally not dangerous in each case.

- Inhaling of sea salt is actually healthy
- Chemical composition and particles size decide about their influence on health risk
- Water and lipid soluble particle material can be efficiently removed from the respiratory tract
- Ultrafine insoluble particles such as soot are not be efficiently removed

Are Soot Particles Dangerous?

Fresh soot particles

- are 30-200 nm in diameter
- contribute only up to 20% of the total aerosol mass in an extreme case (street canyon)
- can pass cell walls
- are surface reactive (damage cells)
- carry e.g. polycyclic aromatic hydrocarbons (carcinogenic)
- can be distributed in the whole human body

Regulations

Epidemiological studies showed an increased health risk with increasing particle mass

EU-Commission allows an upper limit of $50\mu\text{m}/\text{m}^3$ for particles mass for particles $< 10\mu\text{m}$

The major fraction of the total aerosol mass lies in the size range above $0.1\ \mu\text{m}$

→ The aerosol below $0.1\ \mu\text{m}$ accounts only for few percents of the total mass

There are no regulations for the particle number of ultrafine particles

→ Ultrafine particles account for the major number of aerosol particles

Summary

The total particle mass ($< 10 \mu\text{m}$) is a good measure for the particulate air pollution

It might not be the best parameter to determine the health risk of aerosol particles

A large fraction of the particle mass is not dangerous

The major fraction of toxic, carcinogenic, and reactive substances is in the particle range $< 1 \mu\text{m}$

Summary

The ultrafine size range ($<0.1 \mu\text{m}$) dominates the number concentration ($\sim 90\%$) in urban areas

A major contributor here are soot particles emitted by diesel-driven vehicles

Soot particles are believed to have adverse health effects on human body

The health risk nucleation mode particles is not well known yet (large fraction of organic compounds)

Questions

- Is the determination of the particle mass ($>10\mu\text{m}$ or $>2,5\mu\text{m}$) sufficient to estimate the health risk of the local aerosol?
- Is it necessary to introduce an additional parameter such as the ultrafine number concentration?
- Or are concentrations of soot particles a better indicator to estimate the health risk?