Health effects of particles from Diesel engines and automatic wood furnaces

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Recent discussions on health impacts of aerosols have been focused on particle size, since ultra fine particles are not filtered in the upper respiratory tract and penetrate directly into the lung. However, additional parameters like the chemical properties, which are not respected e.g. in nowadays immission limit values, can also strongly influence the health relevance of particles. The present investigation aims at a comparison of health effects of particles from wood combustion and from Diesel engines. These two particle types are of specific interest, *a)*, since Diesel and wood are the major sources of combustion particles and hence potential carriers of carcinogenic compounds like polycyclic aromatic hydrocarbons (PAH), and *b)*, since particles from typical Diesel engines and from typical wood combustion exhibit comparable size distributions and number concentrations (with a peak of the particle number concentration near 100 nm and with concentrations of 10^7 to 10^8 particles/cm^3), while the chemical composition of Diesel and wood particles can be completely different.

Particles from clean Diesel fuels with low ash content consist predominantly of soot and unburned hydrocarbons with only minor concentrations of inorganic ash, while for wood combustion, two cases can be distinguished. Under optimised conditions, as e.g. in properly operated and designed automatic wood furnaces, a high burn-out quality can be achieved. The resulting particles consist mainly of inorganic ash constituents found as salts like KCl, K_2SO_4, $CaCO_3$ and CaO, with a low content of organic carbon, i.e. typically safely less than 5 wt.-%. The second class of wood particles results from incomplete combustion leading to emissions of organic matter, soot, and hydrocarbons. These additional particles can increase the particle mass in wood combustion by more than a factor of two and hence lead to an organic content in wood particles of more than 50 wt.-%. If emitted in high amounts, these particles form an additional fraction of coarse particles. Incomplete combustion is often found e.g. in open fireplaces and simple wood stoves, with very bad conditions resulting from burning wet wood. Hence three types of combustion particles are investigated in the present study:

1. Diesel soot from a modern type, Euro III Diesel passenger car without particle filter;
2. Particles from optimized wood combustion in an automatic furnace (mainly inorganic salts);
3. Particles from incomplete combustion of wood containing both, salts and organic matter.

Due to their size, all particle types will reach the lung surface, once emitted to the ambient air and being inhaled. The influence in the lung is accounted for by biological in-vitro cell tests with a standard culture of V79 lung cells of the Chinese hamster. The cell survival rate as a function of added particle concentration is determined in cytotoxicity tests. Even if the particle concentration does not cause cell death, it can influence chromosome replication during cell division. Such chromosome defects, which are an indicator for the carcinogenic potential, are investigated in micro nucleus tests.

So far, results on cytotoxicity tests are available on particle types 1 and 2. These tests reveal toxic reactions for both types of particles, if a certain concentration limit is exceeded. However, the Diesel particles reveal a significantly higher toxicity than the particles from well designed wood combustion. The wood particle concentration needs to be roughly five times higher than for Diesel particles to cause similar effects. The additional micro nucleus tests as well as investigations on particles from incomplete wood combustion are ongoing.

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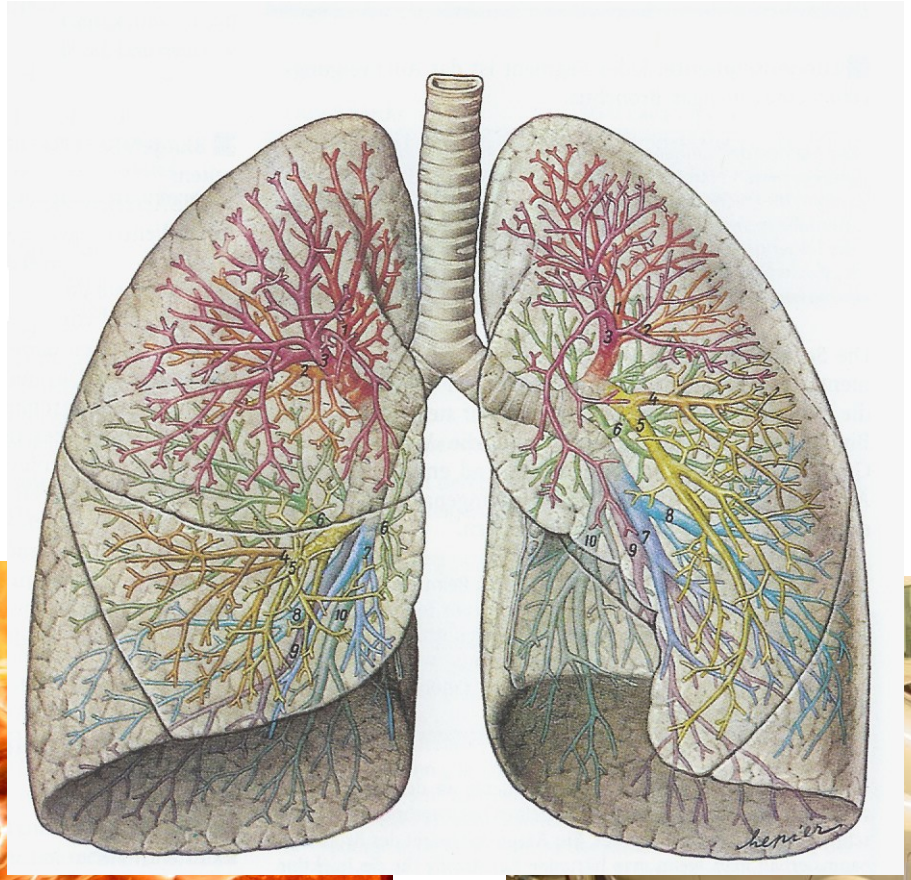
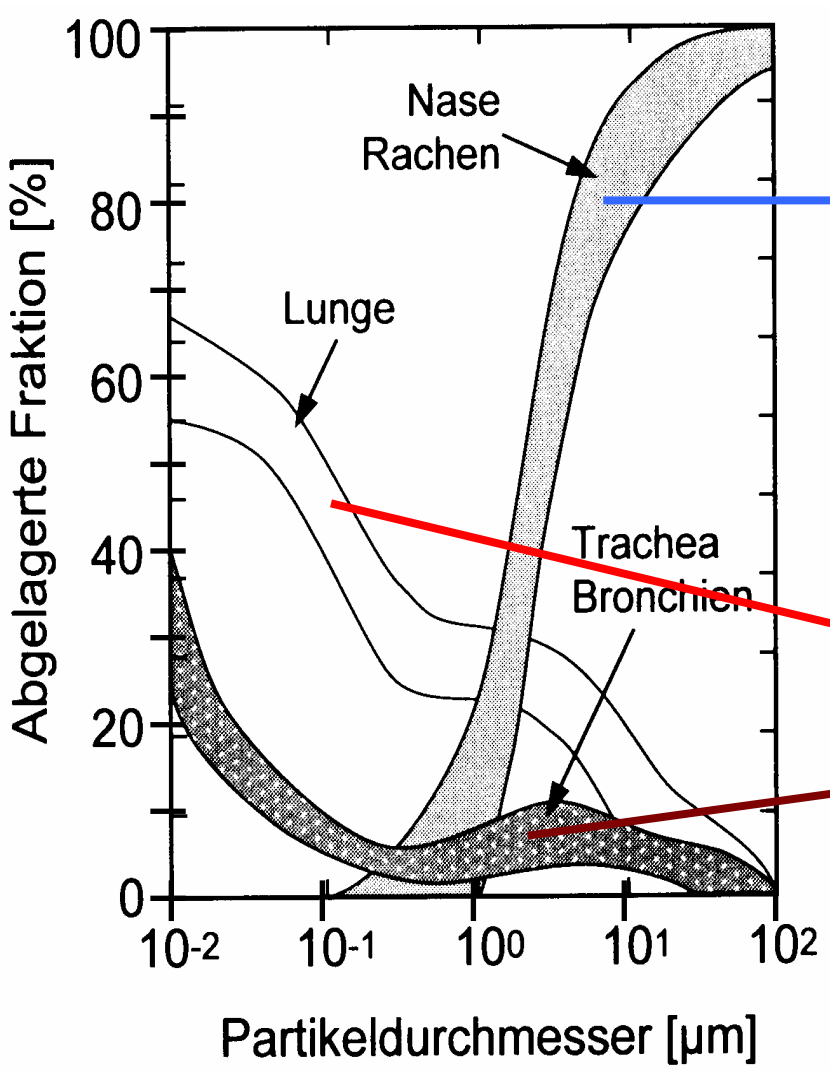
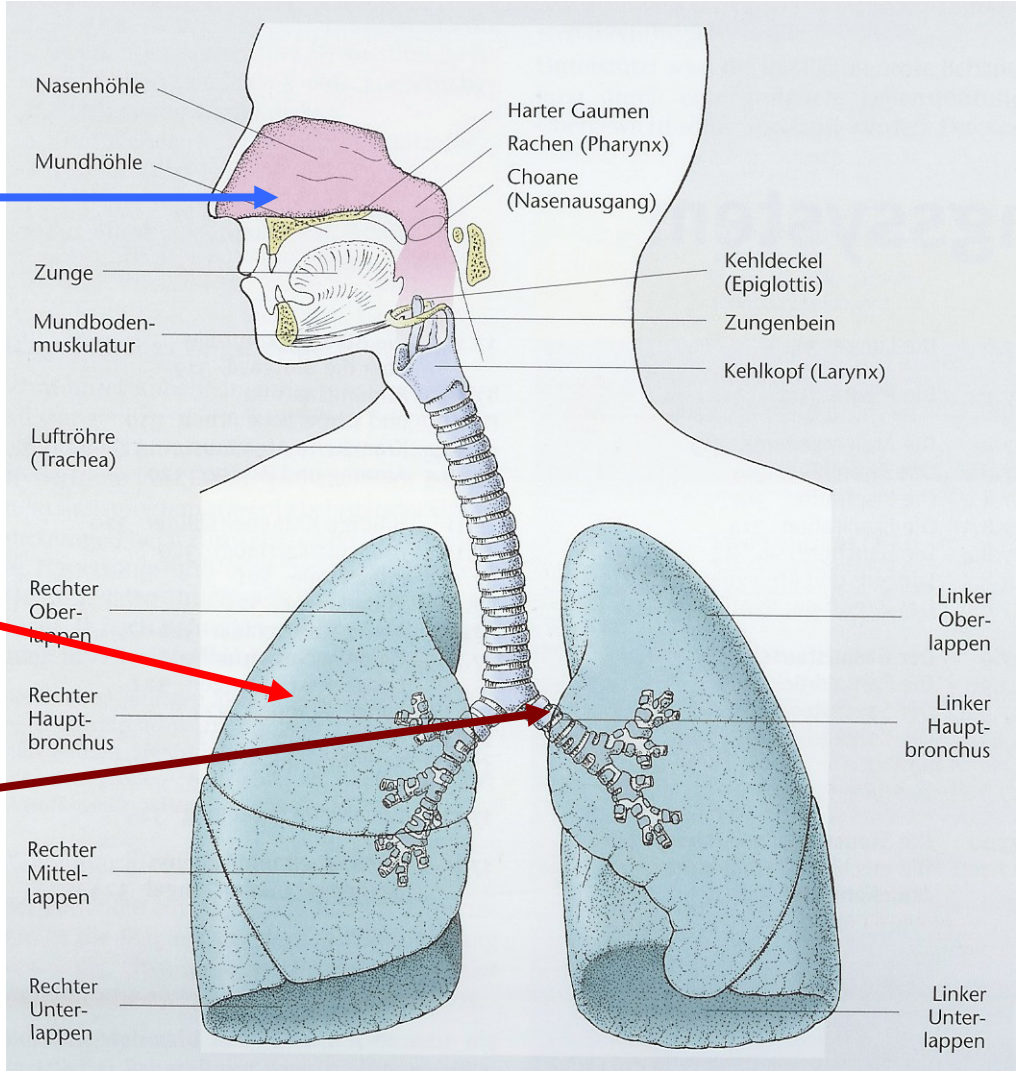
How do different combustion particles influence human health?



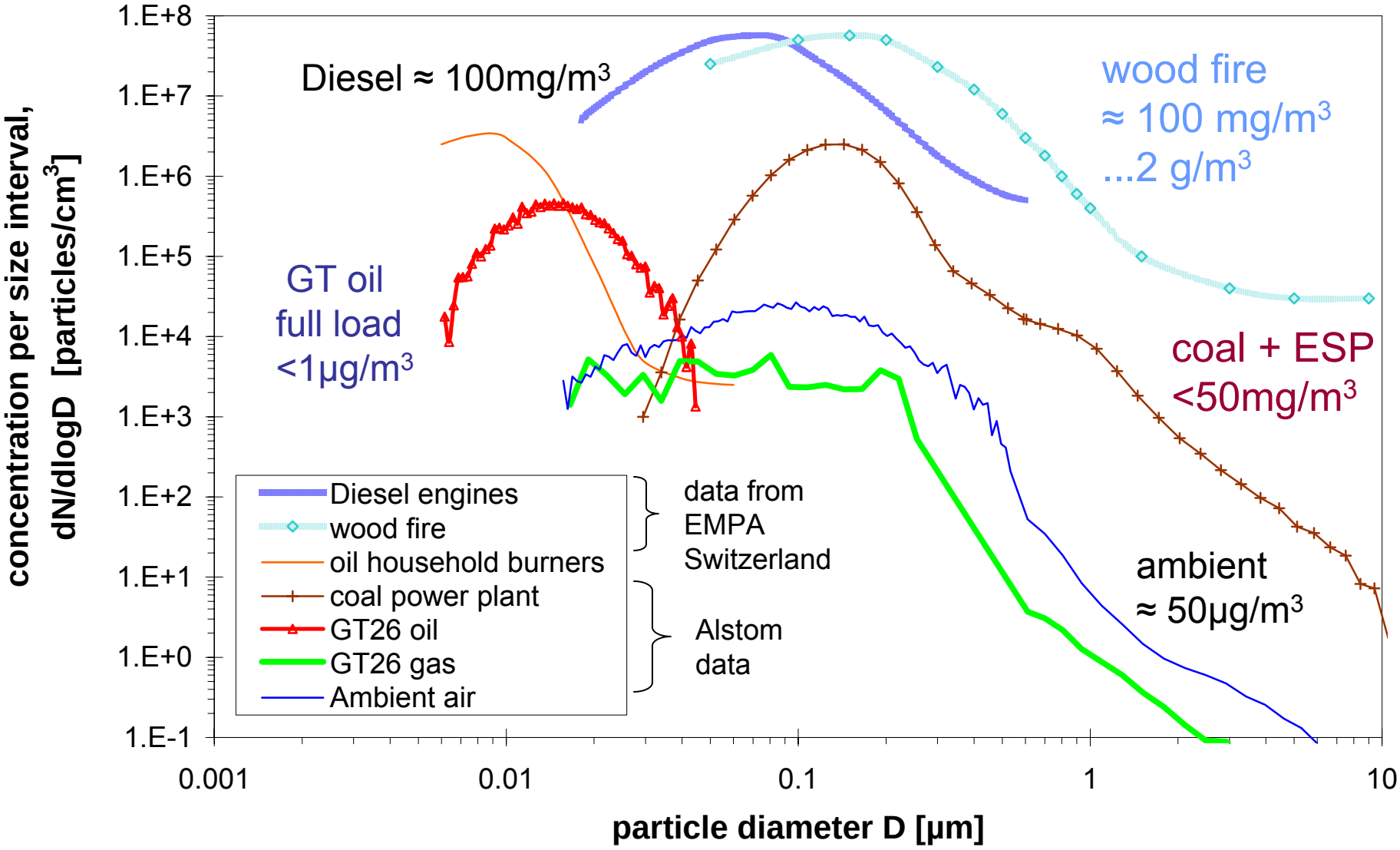
Particle deposition in respitatory tract





 [Health Phys. 12, 173] [Huch et al., 2003] **Verenum**

Comparison: PM10 emissions of different sources



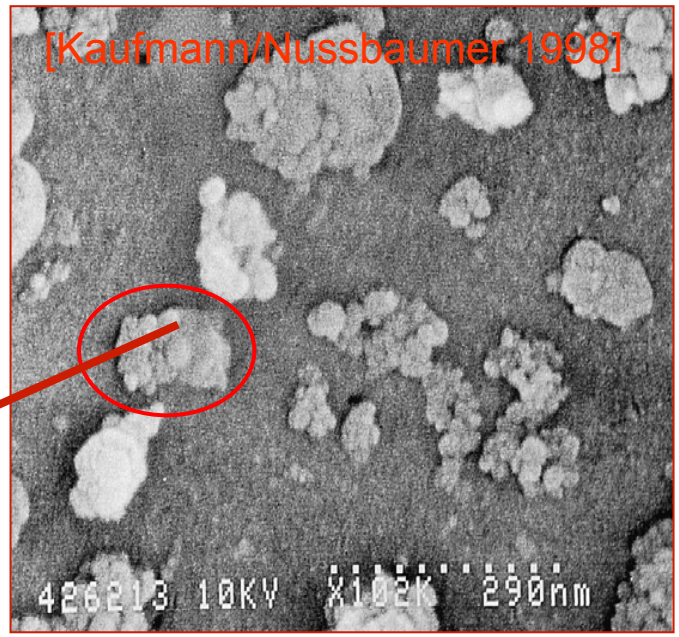
PM10 Emissions of Different Sources

- Main *specific* emitters in particle mass:
  - badly maintained wood fires, old furnaces, open fires with wet wood and/or contaminants
  - old generation Diesel engines
- Main *specific* emitters in particle number, i. e. submicron particles
  - all types of wood furnaces
  - all Diesel engines without particle filter
- Do they also cause similar health effects?

Chemistry of particles from automatic wood furnaces

K, Ca, Na, Cl, S.. →

KCl, K_2SO_4, $CaCO_3$



[Oser et al. 2000]

Wood combustion and Diesel engines

- Chemistry of emitted particles is very different:
  - Diesel: mainly unburned carbon (soot)
  - Wood:
    - mainly salts of K, Ca, Cl, SO_4
    - <5% organic material in modern automatic furnaces
    - high content of unburned material (organic carbon, soot) under bad firing conditions only
- What is the impact on health?

Health effects of Diesel and Wood

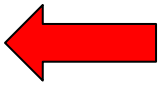
- Ultra fine particles penetrate into lung
- Influence on lung tissue can be very different due to chemistry
- Toxicity of different substances can be investigated by cell culture tests
  - first estimate on toxic reactions inside lung
- Both wood and Diesel particles applied to culture of lung cells of Chinese hamster (V79 standard cells)

Samples generated for health study

Particles sampled after:

A. Diesel engine (Euro III passenger car) 

B. Automatic wood furnace:

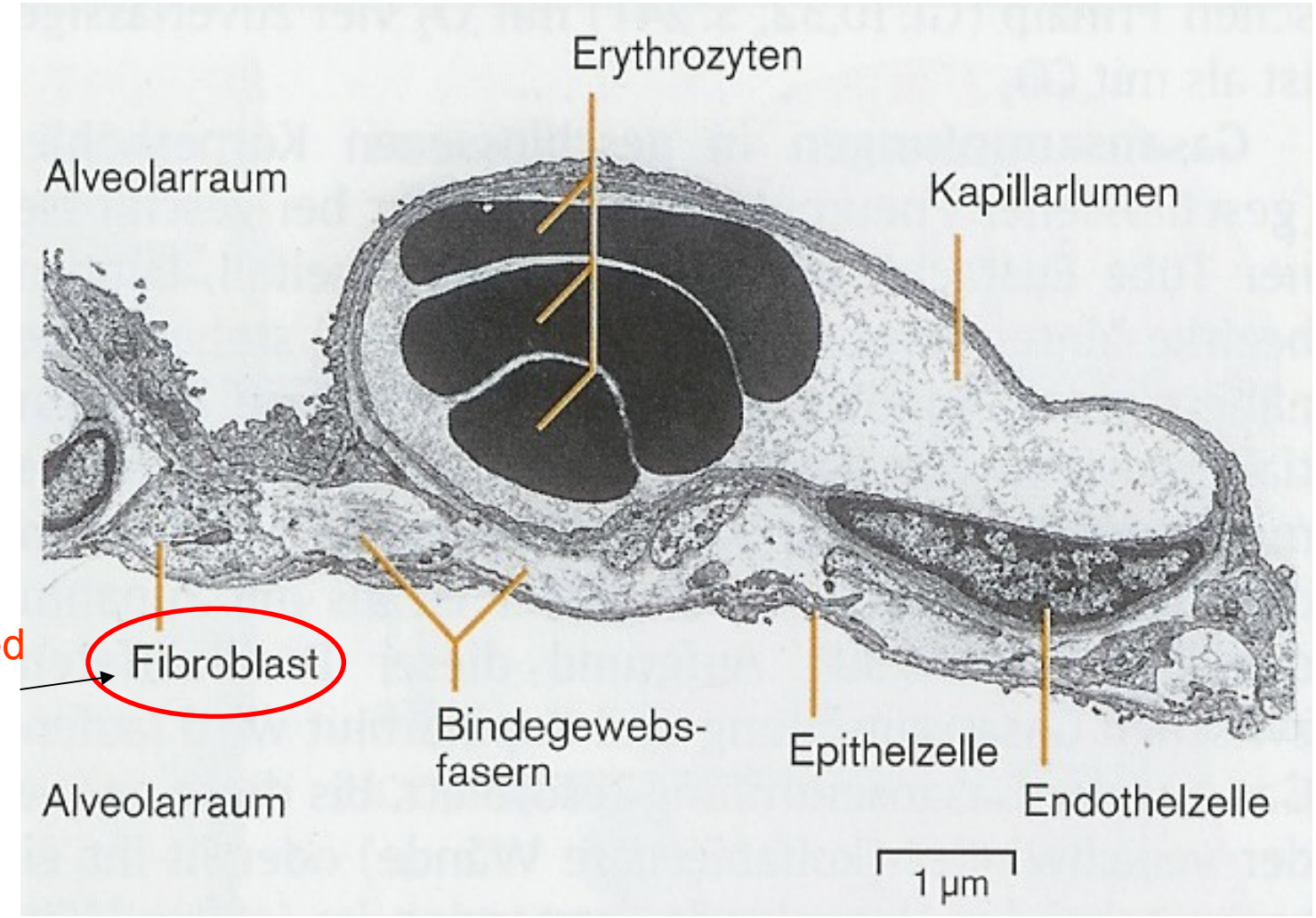
1. Standard operation  eval. in present study
2. Low-Particle-concept (50% lower particle emission)
3. Non-optimal operation (higher emissions)

Particle filters after sampling

0.5 g particle mass

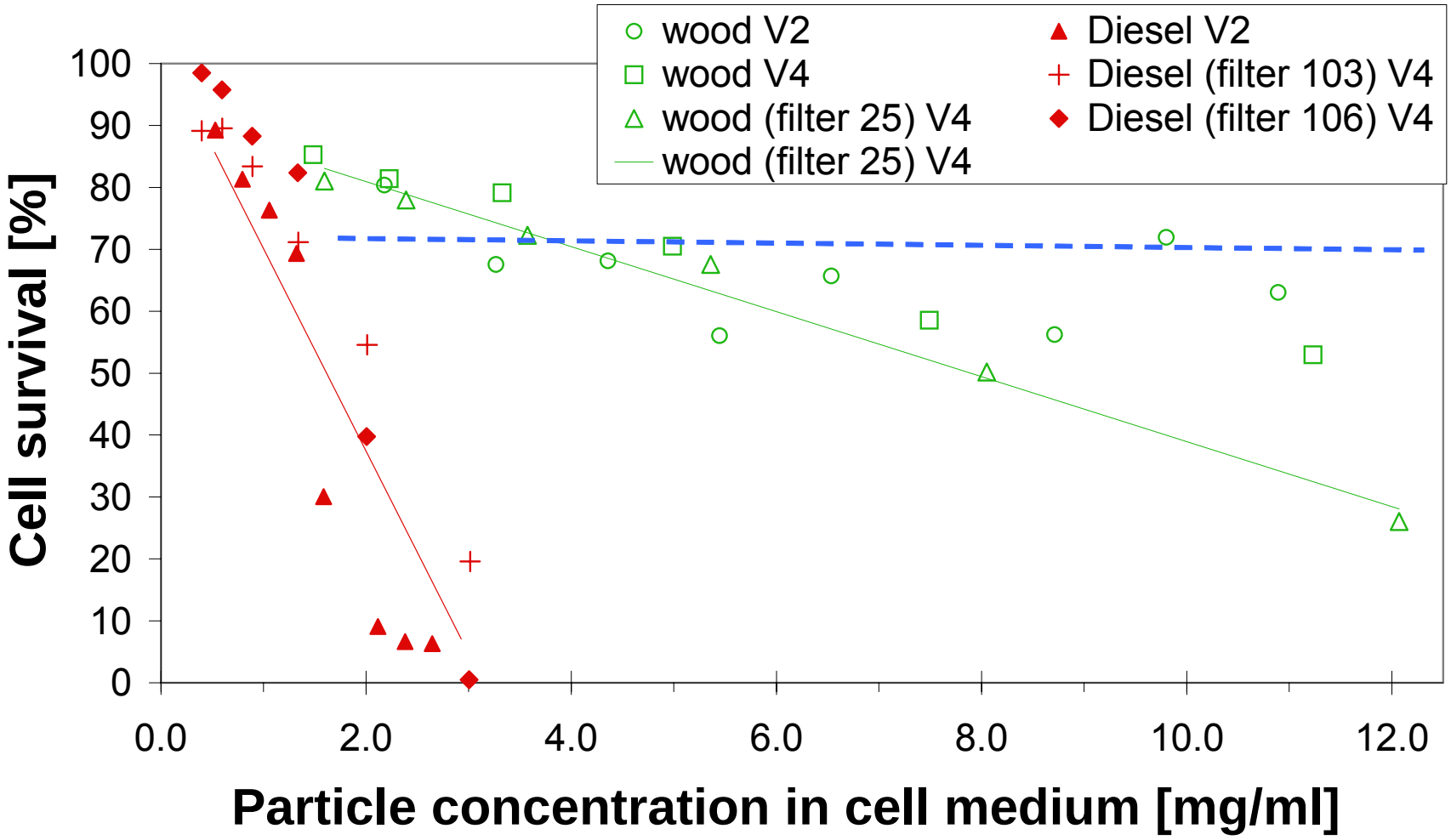
2 g particle mass

Details of alveolar region



cells used for present tests

Comparison between Diesel and wood particle toxicity



Conclusions

- In very high concentrations both particle types are toxic
- Toxicity of Diesel particles is significantly higher at the same particle concentration:
  - up to 100% of cells dead at 3mg/ml
  - at this concentration, toxicity for wood particles is at detection limit of present study
- Ultra fine particles from automatic wood furnaces are less toxic than Diesel soot

Outlook

- ✓ Lower toxicity shown for wood combustion particles, consisting mainly of salts
- ✓ Direct cell tests with K – salts in line with results from wood combustion particles
- • What is the impact of unburned carbons, which result from bad firing conditions?
- • To which extend can health impact further be reduced by low particle firing concept?
- • Investigation of chromosome defects as indicator for carcinogenic potential

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- Swiss Agency for the Environment, Forests and Landscape (BUWAL), Berne
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