Video: VERT Association

- Verification of Emissions Reduction Technology.
- It stands for Best Available Technology BAT and cost effectiveness.
- www.vert-certification.eu

- So that the air is good for breathing - A documentary on the state of particle filter technology

- *The Core objective of VERT® is the minimization of health burden caused by combustion engine emissions, esp. the elimination of Ultra Fine Particles*

Primary & Secondary OH&S Issues

Primary Long Term Health Concerns

- Lung Cancer
- Kidney Cancer
- Other Cancers

Secondary OH&S concerns:

- Irritant
  - Eyes
  - Respiratory System (Throat)
    - Cough / Phlegm
- Pulmonary (Lung) Function
  - Asthma, Pulmonary Fibrosis
- Light Headedness / Nausea
- Visibility
  - DPM can dramatically decrease underground visibility
  - Increased likelihood of accidents

Australian significance

Diesel-fume related lung cancer affects 130 workers a year

TARA on October 4, 2016 at 2:16 pm

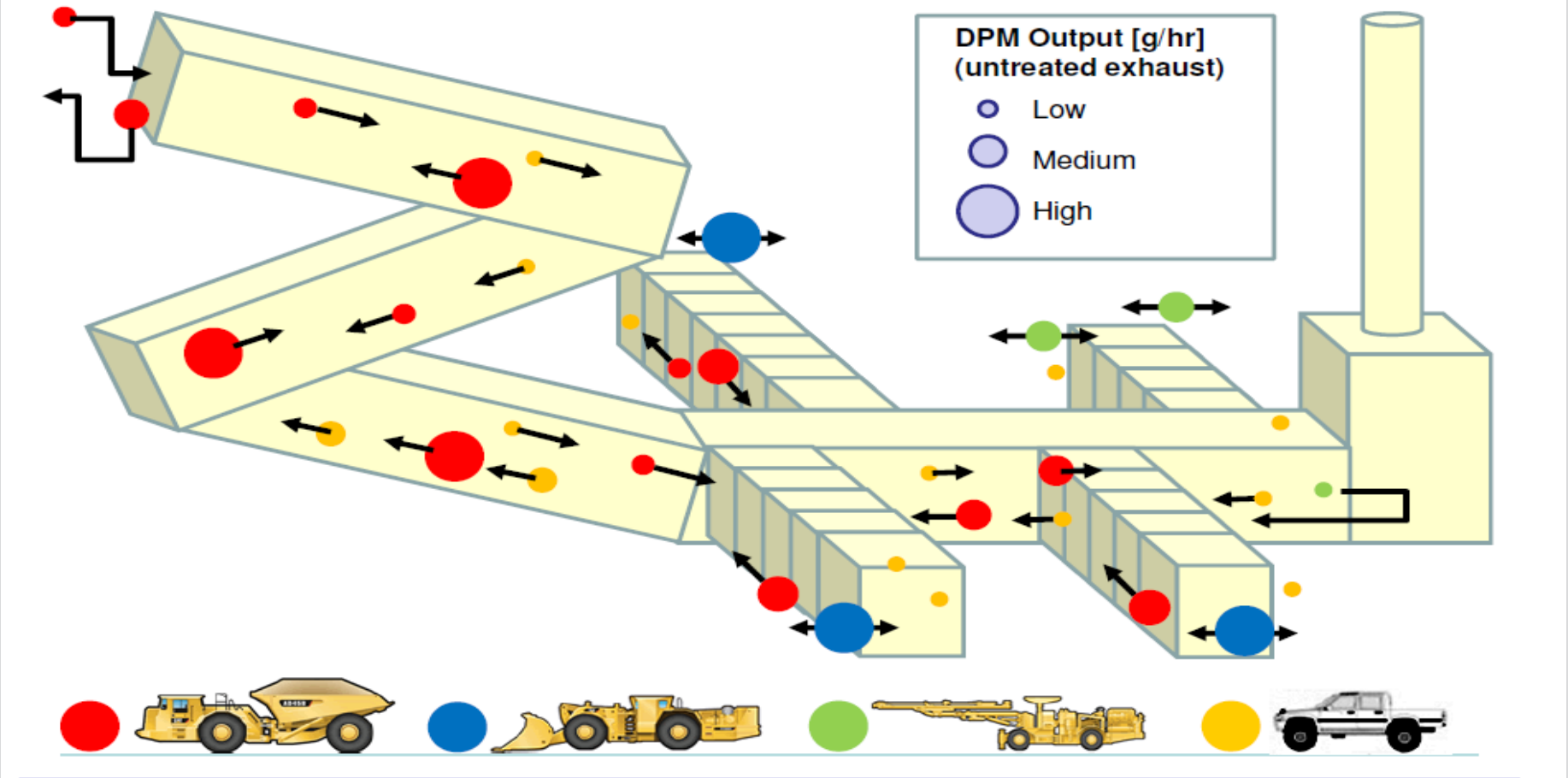
Cancer Council is calling for greater cancer awareness in the workplace, following new estimates that about 130 Australian workers are diagnosed each year in Australia with lung cancer as a result of work-based exposure to diesel fumes.

Legislation

- PM (Particle Mass) U/G Atmospheric limit of 0.1 mg/m^3 (elemental carbon)
- DPM is Class 1 Carcinogen and must be controlled to:
  AS LOW AS REASONABLY ACHIEVABLE / PRACTICABLE
- No PN legislation for mines (atmospheric or tailpipe)
- Certainly now an increased awareness of PN importance and growing support of PN limit
- Example from MDG-29 : GUIDELINE FOR THE MANAGEMENT OF DIESEL ENGINE POLLUTANTS IN UNDERGROUND ENVIRONMENTS
  - For a given 150 kW engine, The minimum ventilation quantity for:
    (i) Gaseous emissions = 9 m3/s
    (ii) Particulate emission with no particulate filter installed = 28 m3/s
    (iii) Particulate emissions with a particulate filter installed = 4 m3/s

    “It takes 3x as much air to disperse particulate emissions as it does gaseous”

DPM signature of a typical mine, with untreated exhaust



- WA Mines Dept.

Ultrafine particle dangers (University of Edinburgh)

- More health effects coming to light:
- AIR QUALITY AND HEALTH WORKSHOP: Fate and transport of ultrafine particles
  - Dr Nicholas Mills, University of Edinburgh (Next 5 slides)

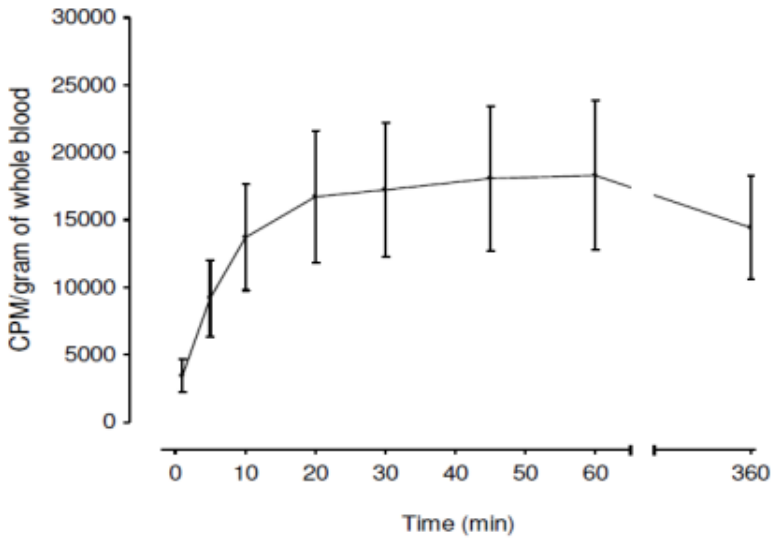
Human exposure studies to understand the effect of air pollution on the heart and blood vessels

PM concentration 300μg/m^3 (median diameter 54nm; range 20-120); particle number = $1.26 \pm 0.01 \times 10^6$ particles/cm^3; NO_x = 4.45±0.02ppm; NO_2 =1.01±0.01ppm; NO = 3.45±0.03ppm; CO = 2.9±0.1ppm; total hydrocarbon 2.8±0.1ppm

Ultrafine particle dangers

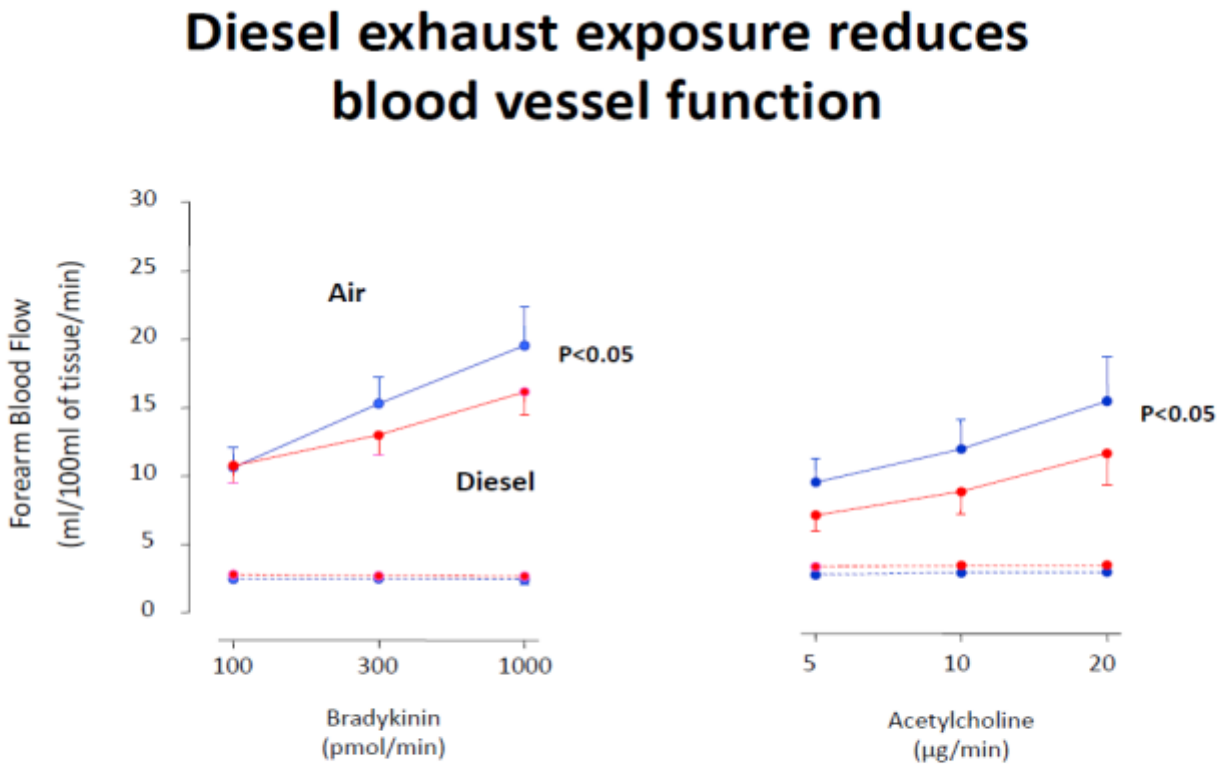
2. Can ultrafine particles translocate into the circulation?

^{99m}Technecium-labelled carbon nanoparticulate (5-20nm) - Technegas

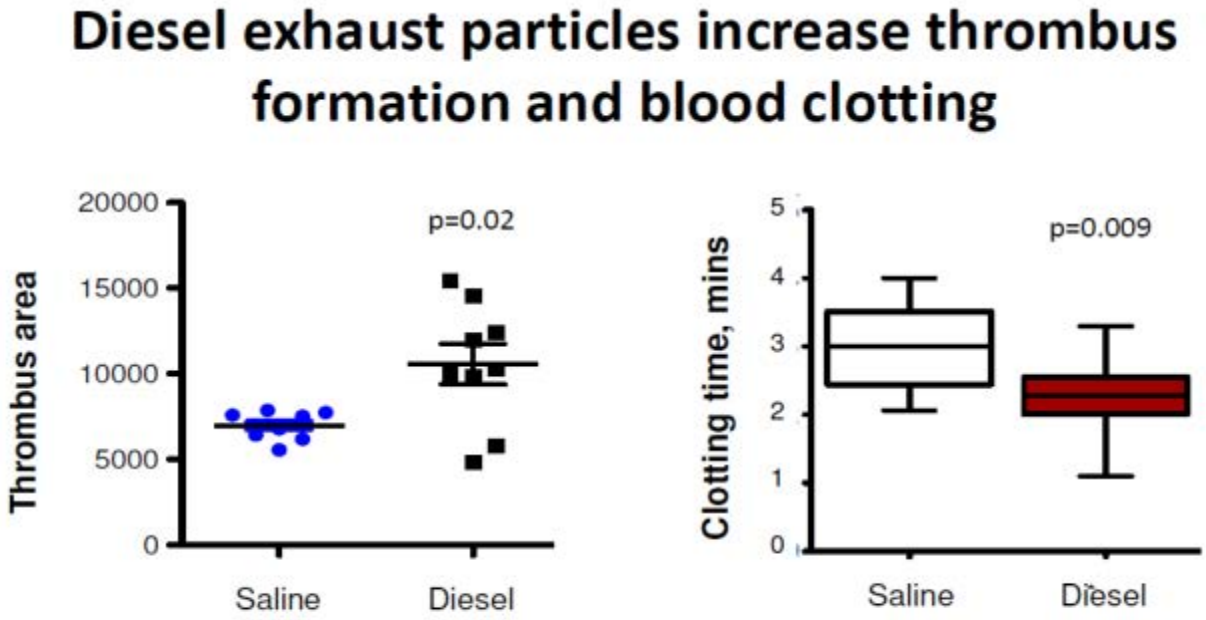


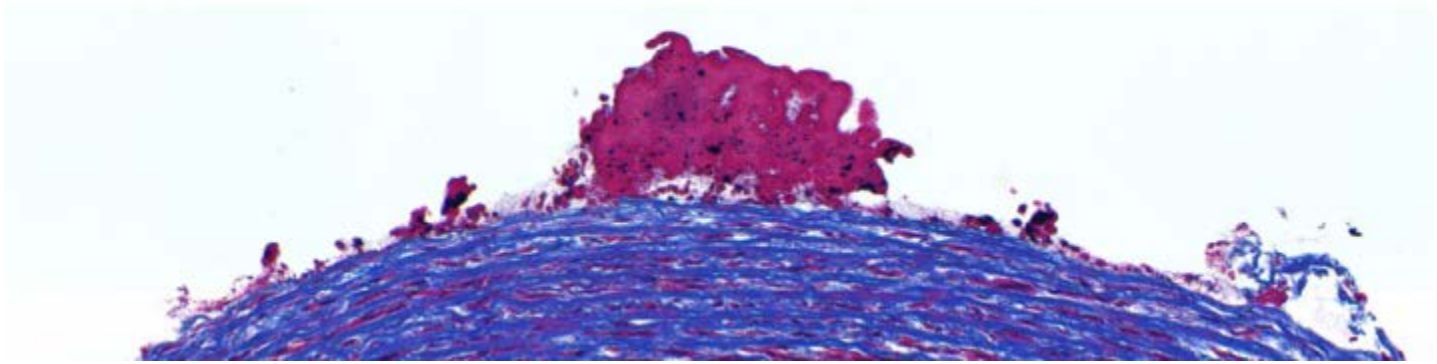
- Radioactivity detected rapidly in the bloodstream

Ultrafine particle dangers



Ultrafine particle dangers



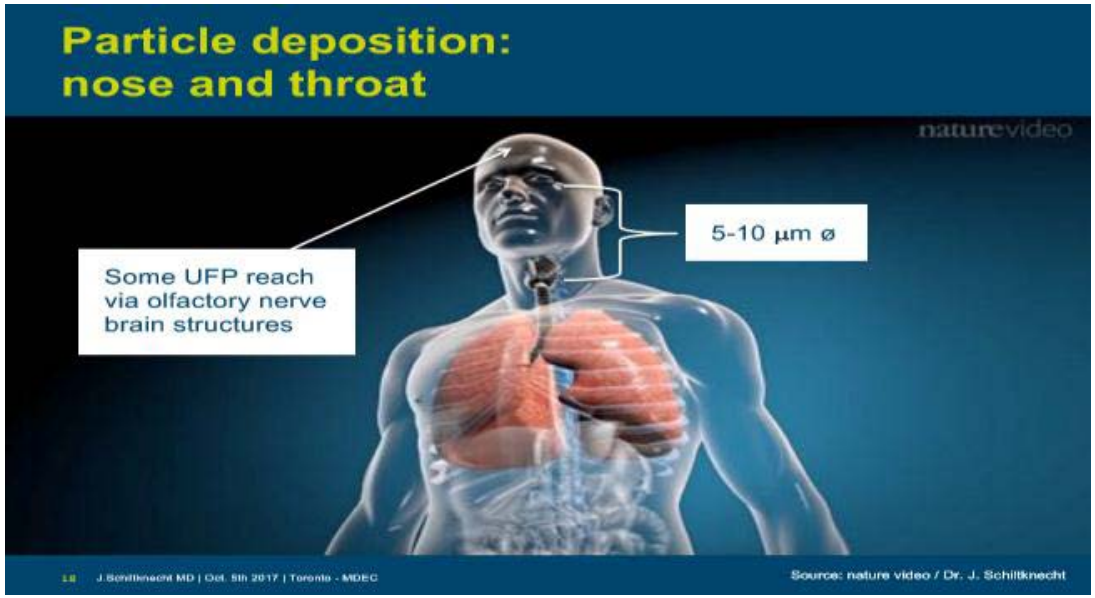


Extracts from presentations of:

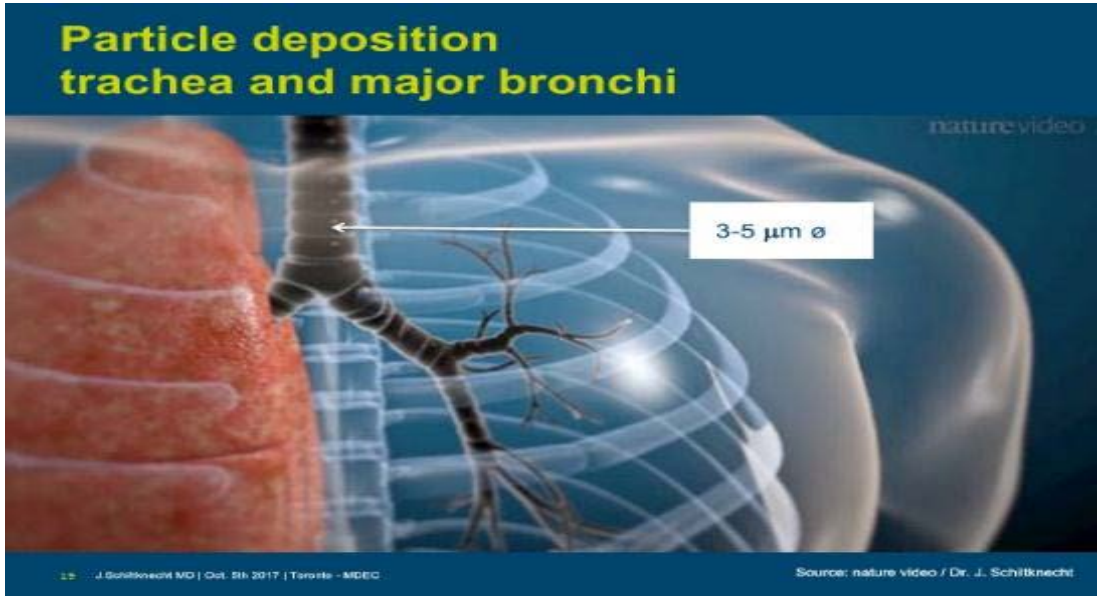
Dr Andreas Mayer, VERT Association, Switzerland

- **The Health Impact of Engine Generated Nanoparticles**
- **Technical Solutions, Adequate Regulations and Monitoring**
  - **MDEC (Mines Diesel Emissions Conference)Toronto 5.Oct. 2017**

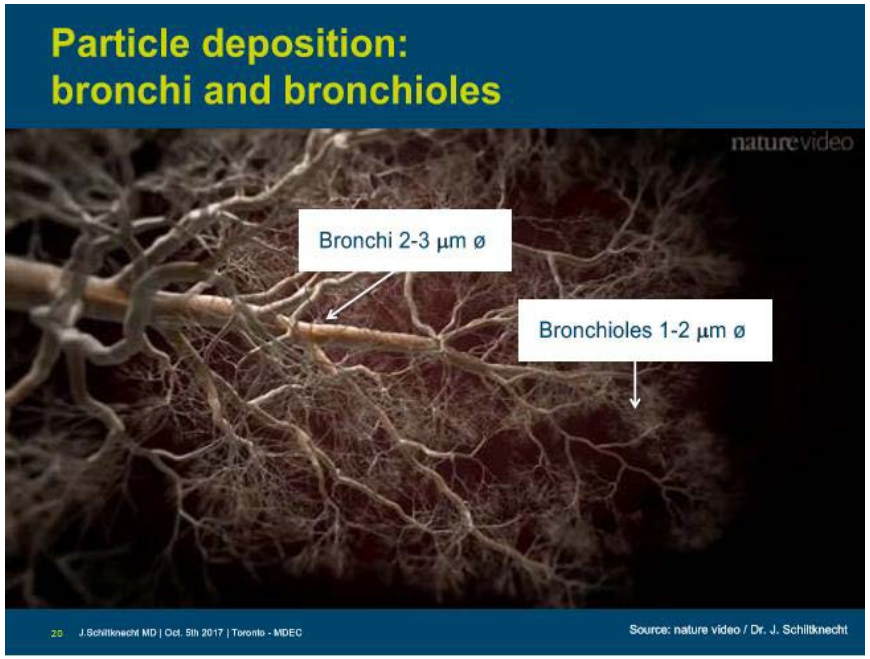
- **Particle Number vs Particle Mass for Health, Metrology and Technology**
- **Time for a Change of The Paradigme,**
  - **AIOH conference, Perth Dec 2015**



The deposition of particles occurs on different levels
Nose and throat: 5-10µmØ



3-5µmØ reach the bigger air conducts and stick to the mucus pushed to the mouth and swallowed or expectorated.



Even smaller particles are still captured and eliminated by the the “mucociliary elevator”:

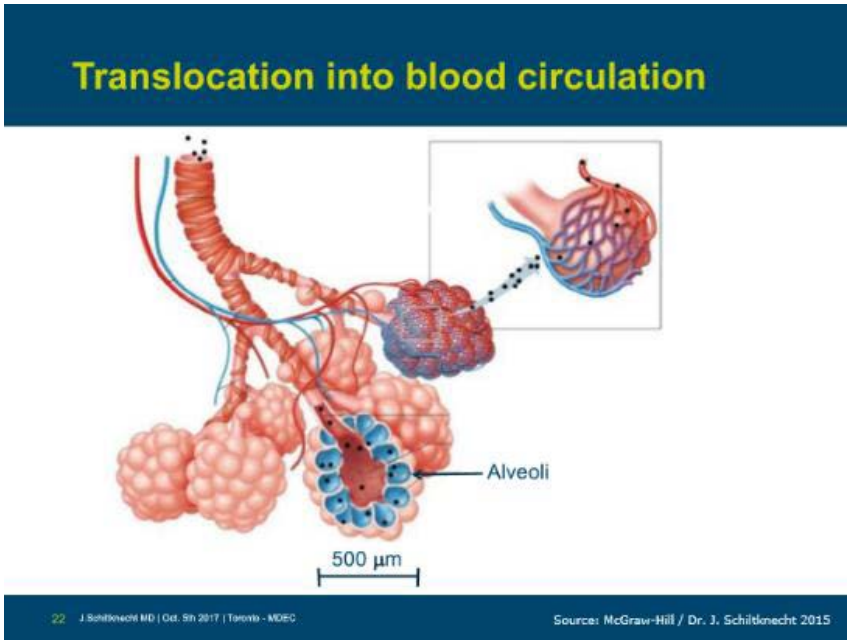
- 2-3 µmØ in the bronchi,
- 1-2 µmØ (1000- 2000 nmØ) in the bronchioles.

Lung evolved over millions of years to have defense mechanism against solid particles from natural sources (> 2 µmØ)

Everything changed when industry produced nanoparticles < 1 µmØ, resulting from technical combustion on a very large scale.

The nanoparticles reach the alveoli.
That is where the drama begins:

Part of the nanoparticles under 1µmØ and smaller translocate though the subtle respiratory membrane.

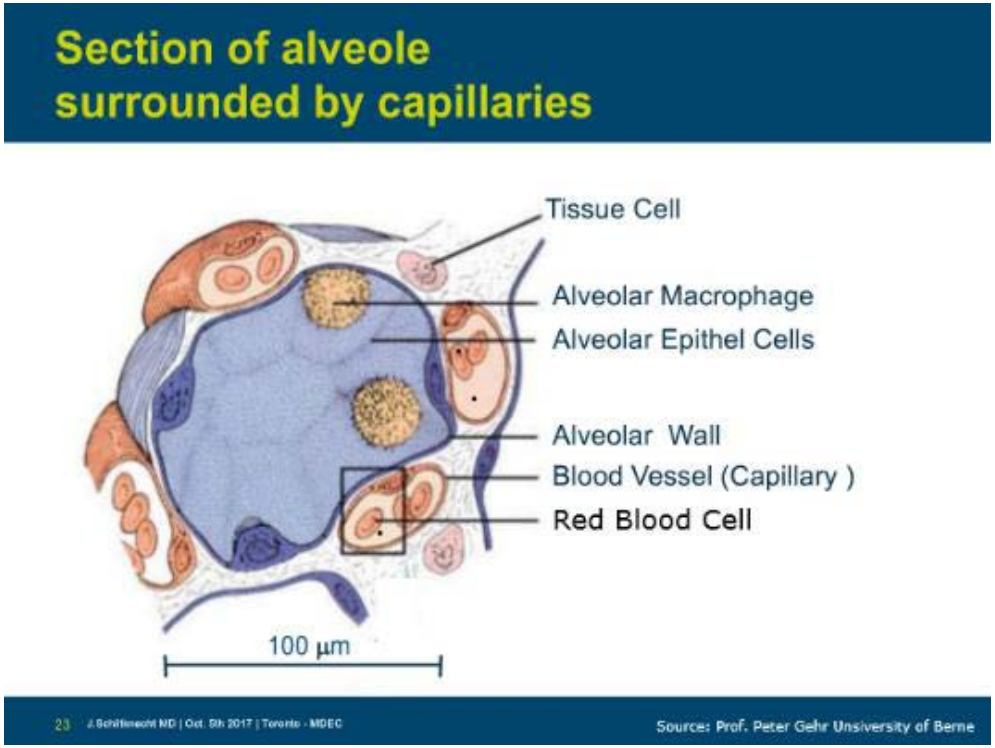


In blue is alveoli framing a common space in section.

Each alveoli is enmeshed by a tight net of extremely thin blood vessels, the lung capillaries.

The black dots symbolize the particles translocated into the blood circulation.

We have 500 million of alveoli, their inner surface totals 150 square meter and the network of arteries in the lungs has a total length of about 2000 km.

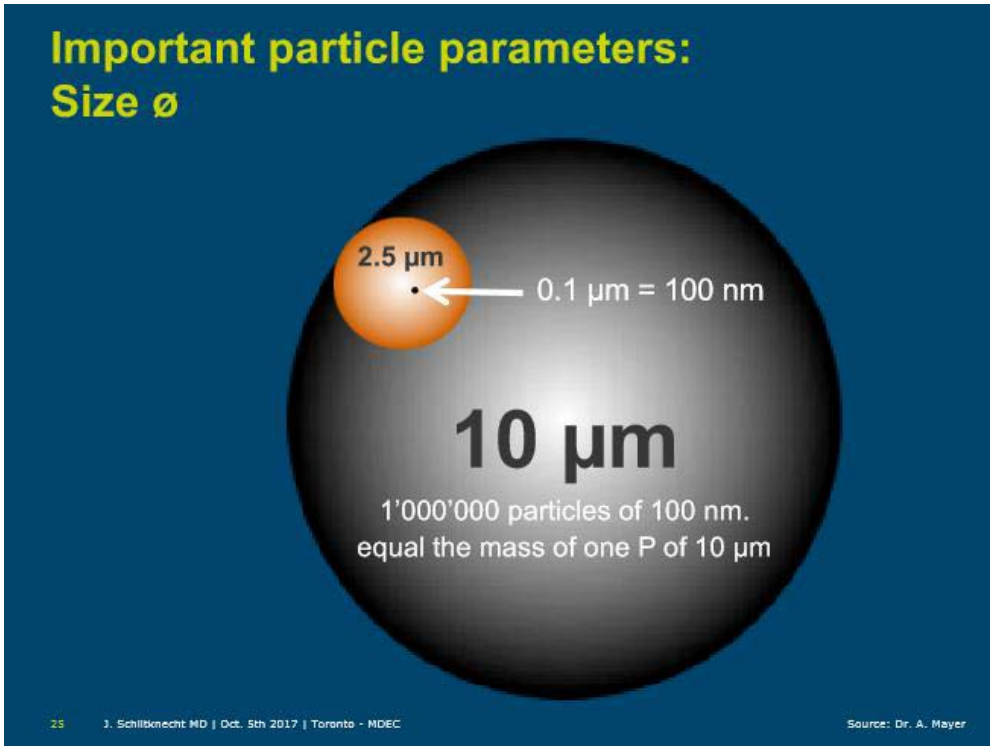


Section through an alveoli: Cells with nuclei (blue), fitting together like several eggs fried

The capillaries with the red blood cells are in tight contact with the alveolar cells, and constitute together the subtle alveolar membrane, where the gas exchange occurs.

The blood circulation distributes the particles;

- They may reach all organs and cells.
- That explains the impact of vehicle exhaust on different organs, first and foremost, the heart and circulation.
- Nanoparticles also travel from the nose via the olfactory nerve to the central nervous system, circumventing the blood brain barrier. Contingent to this finding, Parkinson's and Alzheimer's disease are more frequent in areas near heavy traffic.



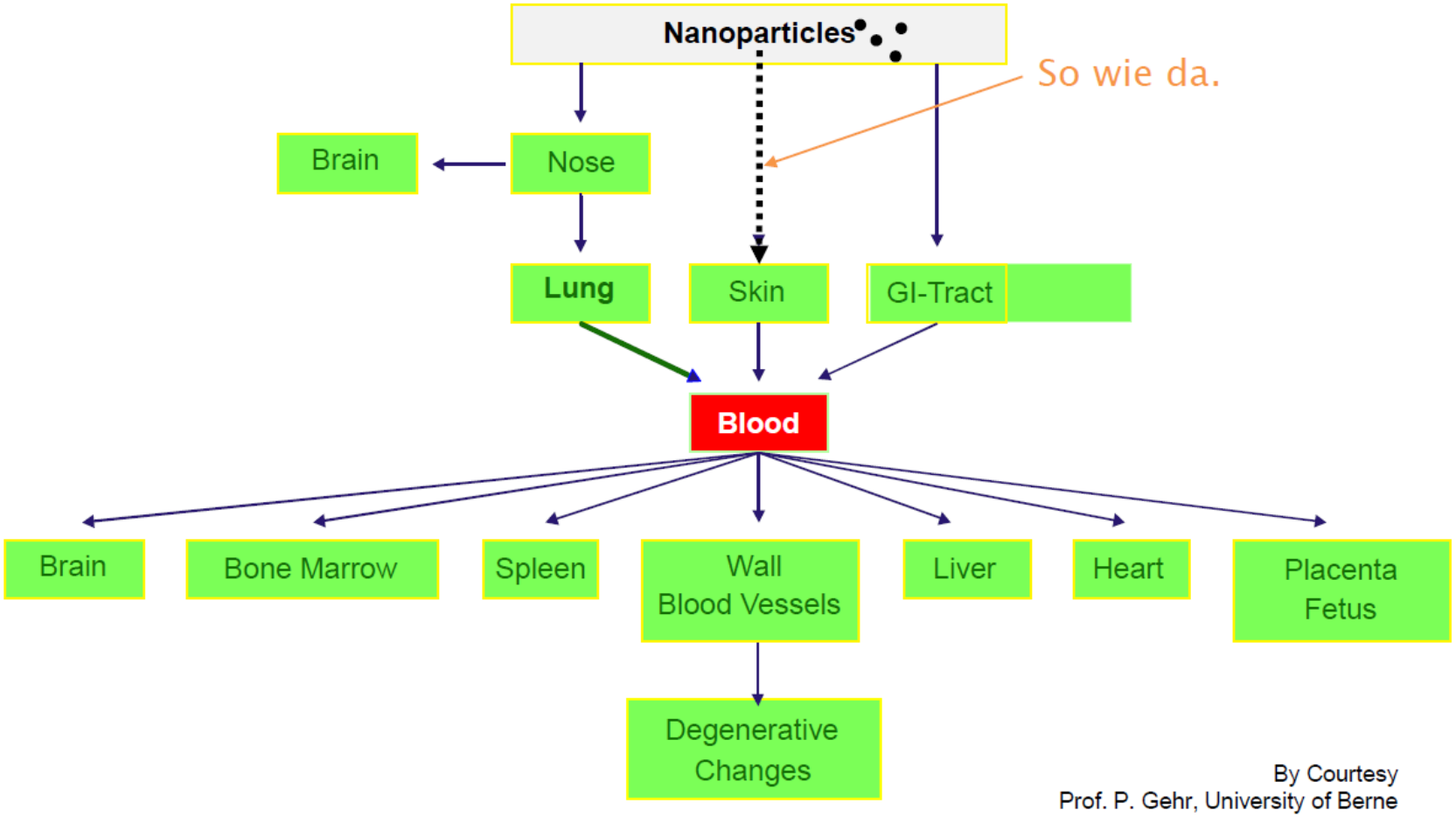
Size is the first criterion to decide whether a particle can become a toxic air contaminant TOC or not.

Particles > 10µmØ settle before they reach mouth and nose.

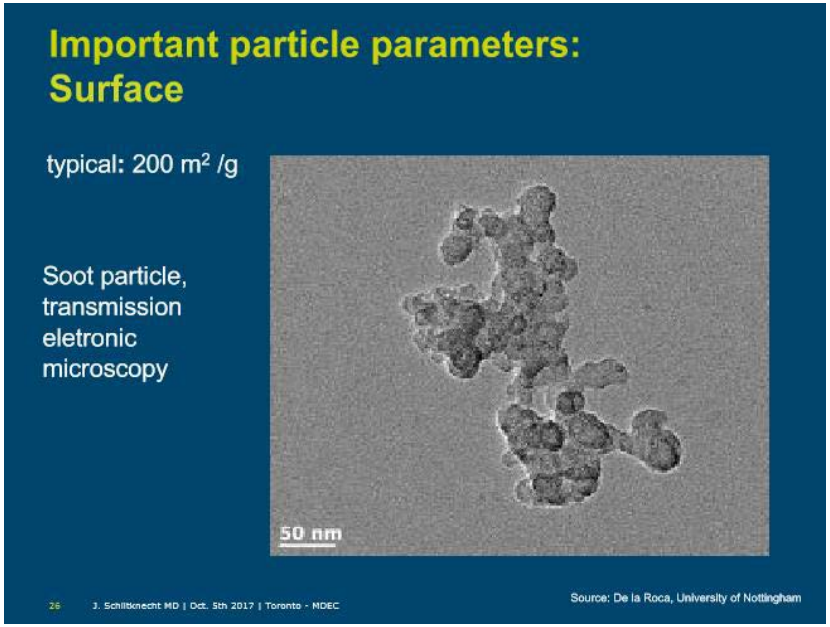
Particles > 1 µmØ are deposited by impaction onto the mucus.

The small size fraction in the range of 20-500 nmØ can get into the alveoli.

Translocation of Nanoparticles



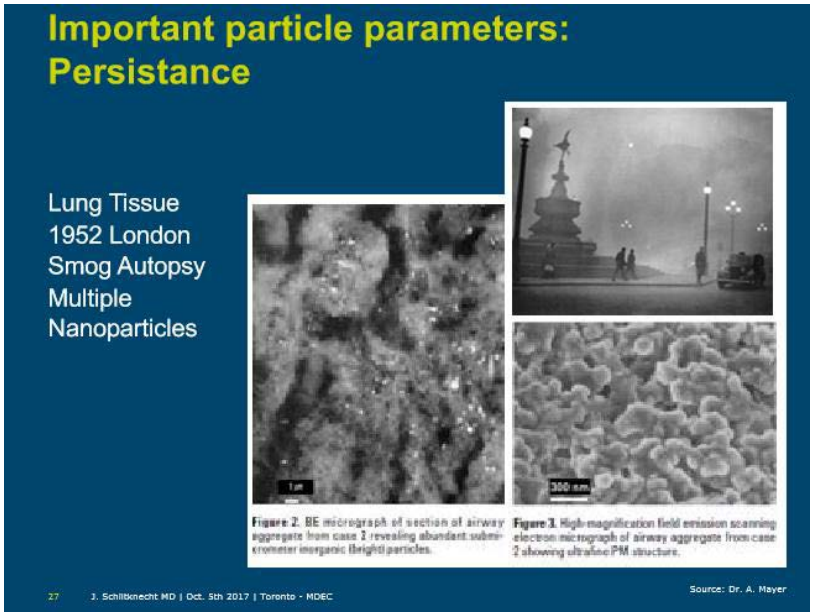
By Courtesy
Prof. P. Gehr, University of Berne



All biologic processes take place on surfaces.

Primary soot particles are quasi-spheres of 20 nmØ and not porous. The relative surface is 200 m² per gram – imagine!

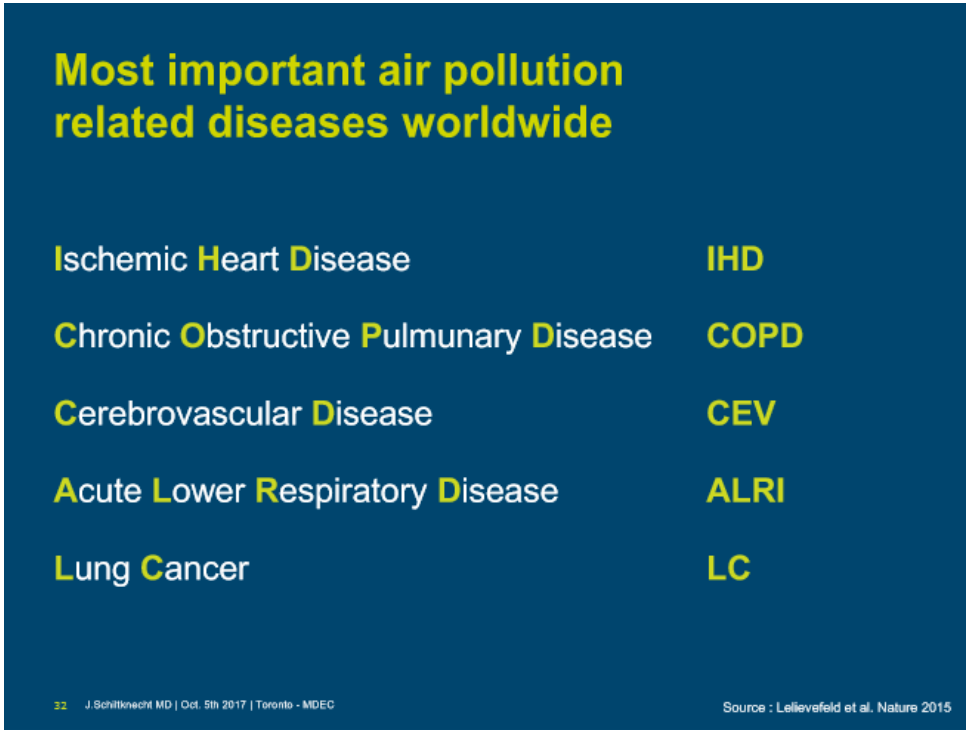
Coated with PAH, metal oxides from engine wear and lubrication, UFP are ready to react with whatever cell or cell organelle they come in contact with.



Combustion generated nanoparticles persist in the organism. They are not “digested” easily, not metabolized - the organism fights an endless energy consuming fight.

Repair mechanisms are overwhelmed, premature aging and more cancer cases are the consequence.

Soot is relentless as demonstrated by the lungs of the Stone Age mummy Ötzi, who was released by a melting glacier and London smog victims



Heart attacks (30%), stroke (40%) and cancer (20%) are the main UFP-related diseases that lead to premature mortality.

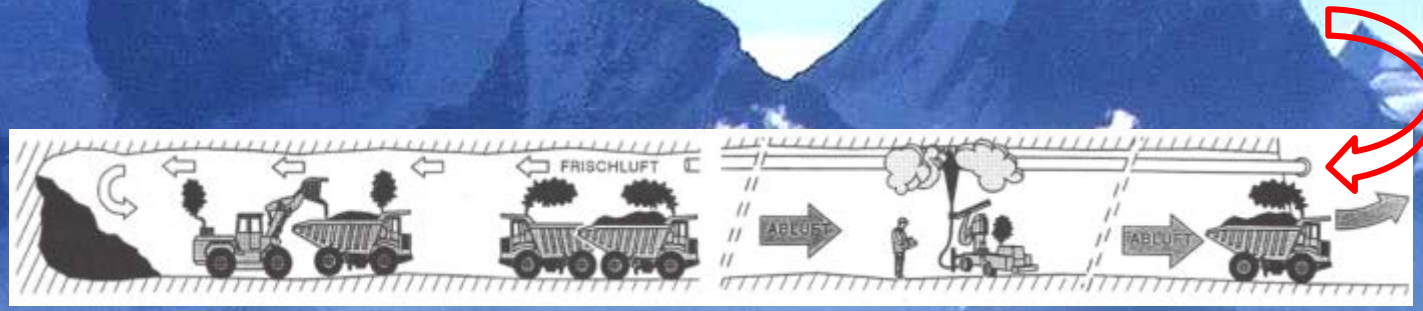
This is the finding of a new extended meta-study by the Harvard School of Public Health/Boston and the German Max-Planck institute Mainz in 2015.

The WHO classification of Diesel exhaust as a severely carcinogenic agent in CLASS1 (like asbestos) has been confirmed by studies conducted in mines.

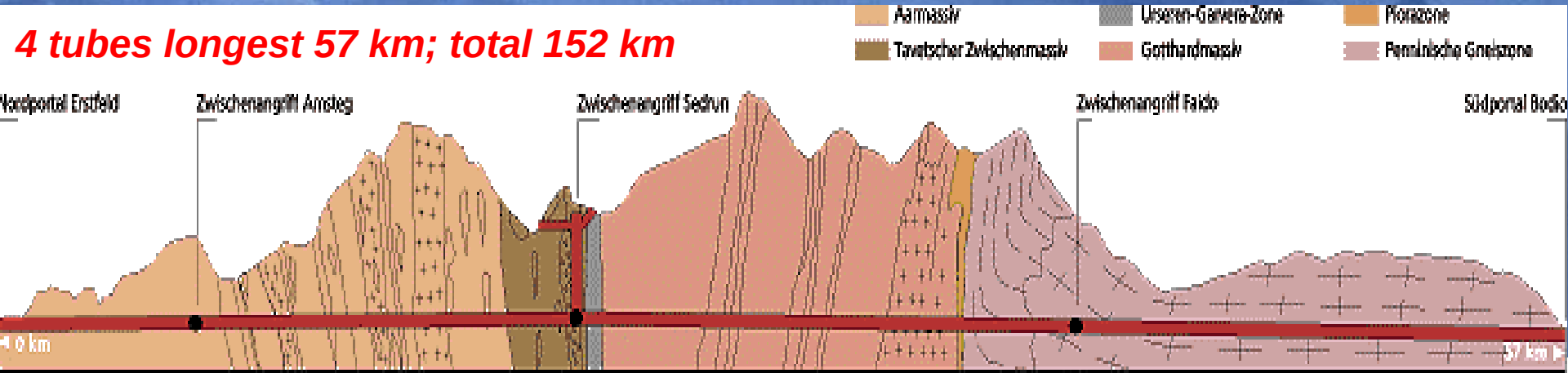
1993 the NEAT-Tunnel – big step

Occ.Health Requirement by SUVA, TBG, AUVA

«Concentration of solid submicron particles < 100 µg/m³ within three years» = reduction by > 50 times



4 tubes longest 57 km; total 152 km



Why has Soot Elimination highest Priority ?

Engine Emissions compared to occ.health thresholds (MAK) in 1994 at S = 500 ppm and dilution 1:40 (regulation 4 m^3/kWmin)

	Gases				Aerosols	
	CO	**NO**	**NO_2**	**SO_2**	**PM=EC + OC**	**H_2SO_4**
Emissions [mg/Nm^3]	**1000**	**2700**	**300**	**100**	**250**	**25**
Limit Values (MAK) In Switzerland 1994 [mg/Nm^3]	**35**	**30**	**6**	**5**	**0.1 (K)**	**0.1**
Required Dilution	**> 28**	**> 90**	**> 50**	**> 20**	**> 2500**	**250**

Solution required within 3 yrs for in-use tunneling engines

History of UFP-Risk and Reduction from ICE

- 1775 P.Pott Cancer in Chimney Sweeps
- 1888 J.Aitken invents CNC
- 1909 englishe occ.health MD investigate helth effects of nanoparticles in mines
- 1958 P.J.Lawther: increase of lung cancer in London und Wales due to traffic
- 1959 Johannisburg Convention: influence of number surface and size
- 1969 VDI: limitation of soot emission of trucks because of visibility
- 1970 US Clean Air Act – no limits for particle emissions
- 1980 Corning publishes the DPF priciple
- 1982 first PM limits for Diesel LDV in USA (0.6 g/mi)
- 1984 Particle Filters developed in Switzerland for Daimler for California
- 1987 IARC declares Diesel PM as «potential carcinogen» → 2012 «class 1»
- 1993 VERT-Projekt: DPF in Tunneling in Switzerland
- 1993 6-cities study
- 2000 Peugeot starts selling Diesel+DPF in LDV
- 2002 DPF in Switzerland for construction, later for buses, ships, locomotives
- 2007 EU enforces DPF by introcucing PN limit values – following Switzerland
- 2010 LEZ London, followed by over 1000 LEZ in Europe
- 2015 100 millions OEM-vehicles with DPF, 500'000 retrofits construction and others

London Smog 1952

during one week died
6’000 persons
6’000 more next month

London had replaced the electric tram by Diesel buses 6 month before

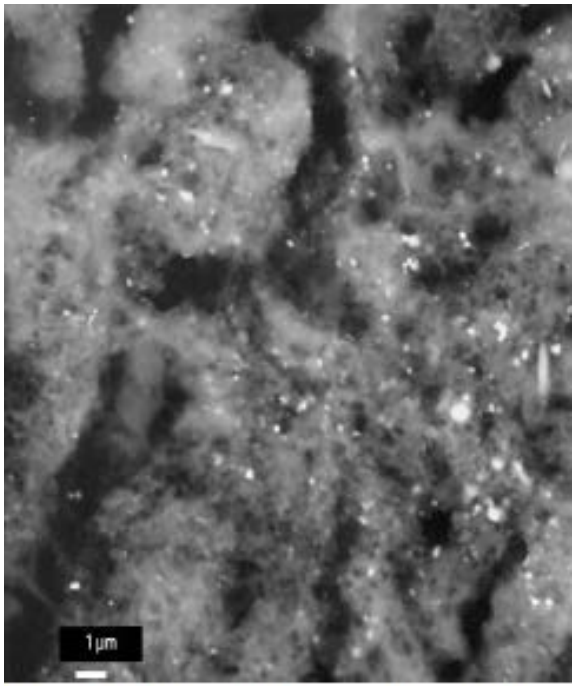


Figure 2. BE micrograph of section of airway aggregate from case 2 revealing abundant submicrometer inorganic (bright) particles.

Diesel Exhaust Carcinogenic

1988 class 3, 2012 class1

International Agency for Research on Cancer

World Health Organization

PRESS RELEASE
N° 213

12 June 2012

IARC: DIESEL ENGINE EXHAUST CARCINOGENIC

Lyon, France, June 12, 2012 -- After a week-long meeting of international experts, the International Agency for Research on Cancer (IARC), which is part of the World Health Organization (WHO), today classified diesel engine exhaust as **carcinogenic to humans (Group 1)**, based on sufficient evidence that exposure is associated with an increased risk for lung cancer.

Based on epidemiologic evidence in 8 US metal mines

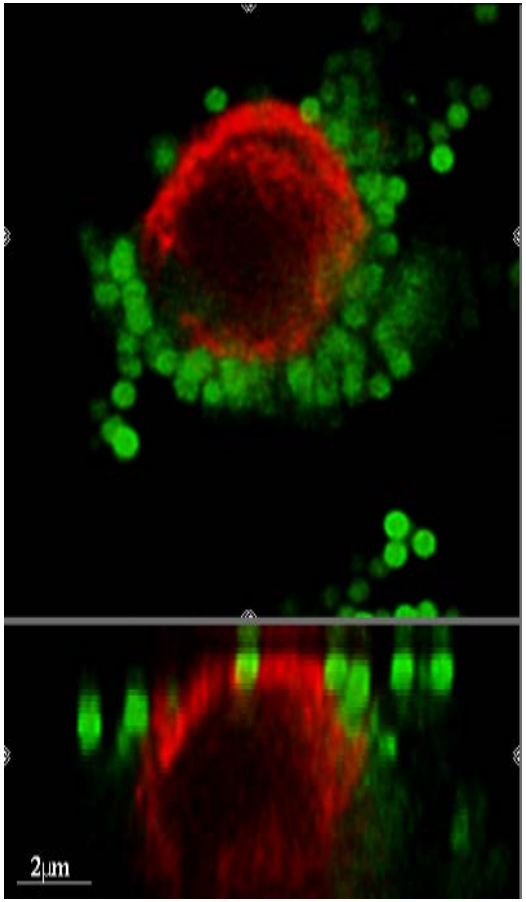
with 2 lung cancer victims in 100 workers – after 10 years work

exposed to Diesel particle concentration of 100'000 P/cc

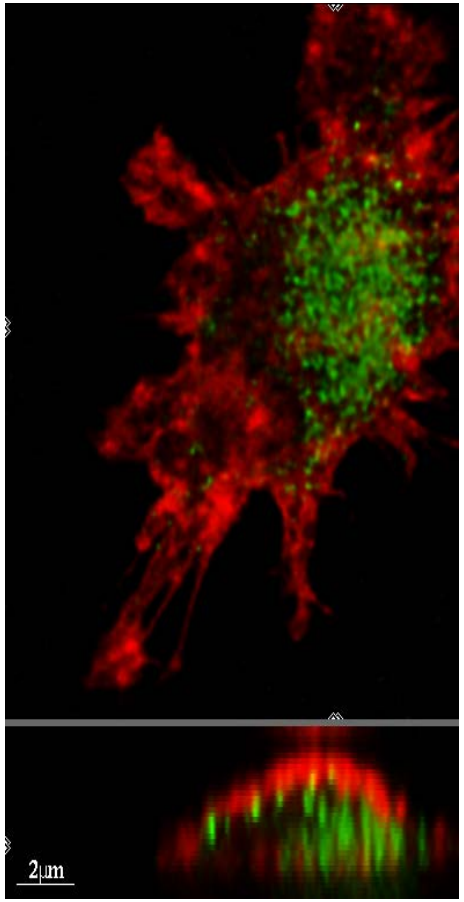
General population around 2 in 5,000

Particle Size Penetrating Membranes

1000 nm
Polystyrene Particles



78 nm
Polystyrene Particles



Laser Scanning Microscopy

Solid particles smaller than 500 nmØ reach the alveoli.

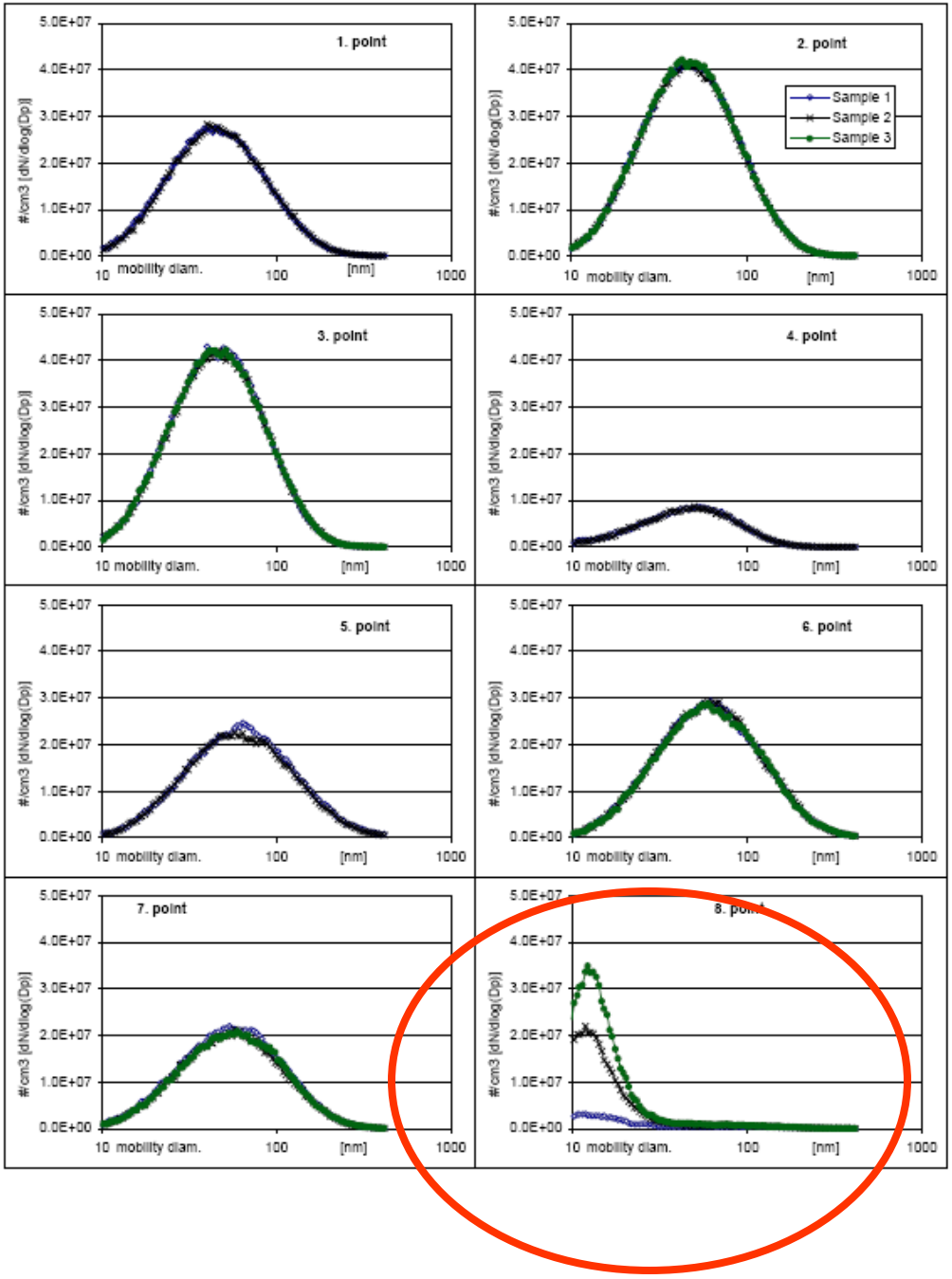
About 5% of them translocate readily into the blood stream.

They may infiltrate the bladder, the liver, the brain – all of our organs.

Small particles around 100 nmØ, the typical size of Diesel UFP, may enter the cell causing damage to the DNA of the genes.

This demonstrates, why size matters and not mass, and why particles have to be monitored by number

B. Rothen-Rutishauser, University Berne



Size distributions

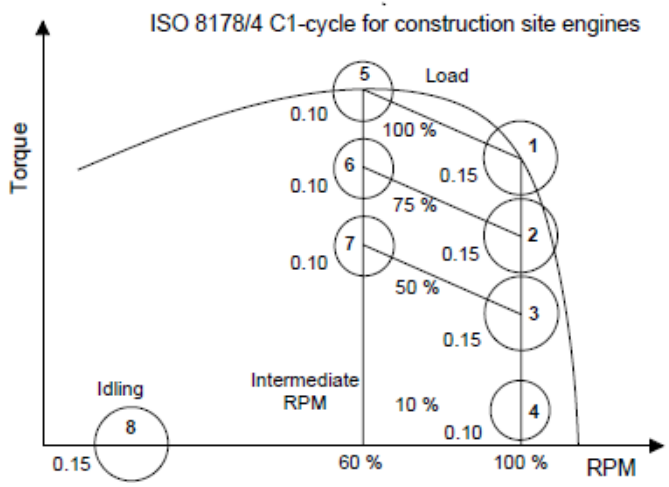
Liebherr Diesel

110 kW

8 operation points of
ISO 8178/4 C1 test cycle

OP 8 = idle

Sampling: 300°C,
Dilution Ratio DR=100



Beijing 2012 and 2013
Antikorrelation PN/PM due to Scavenging

Beijing 20.12.2012 9:00
day before predicted apocalypse

DiSCmini: 90'000 P/cm^3
(60 nm → 20 µg/m^3 BC)

PM2.5 official: 182 µg/m^3

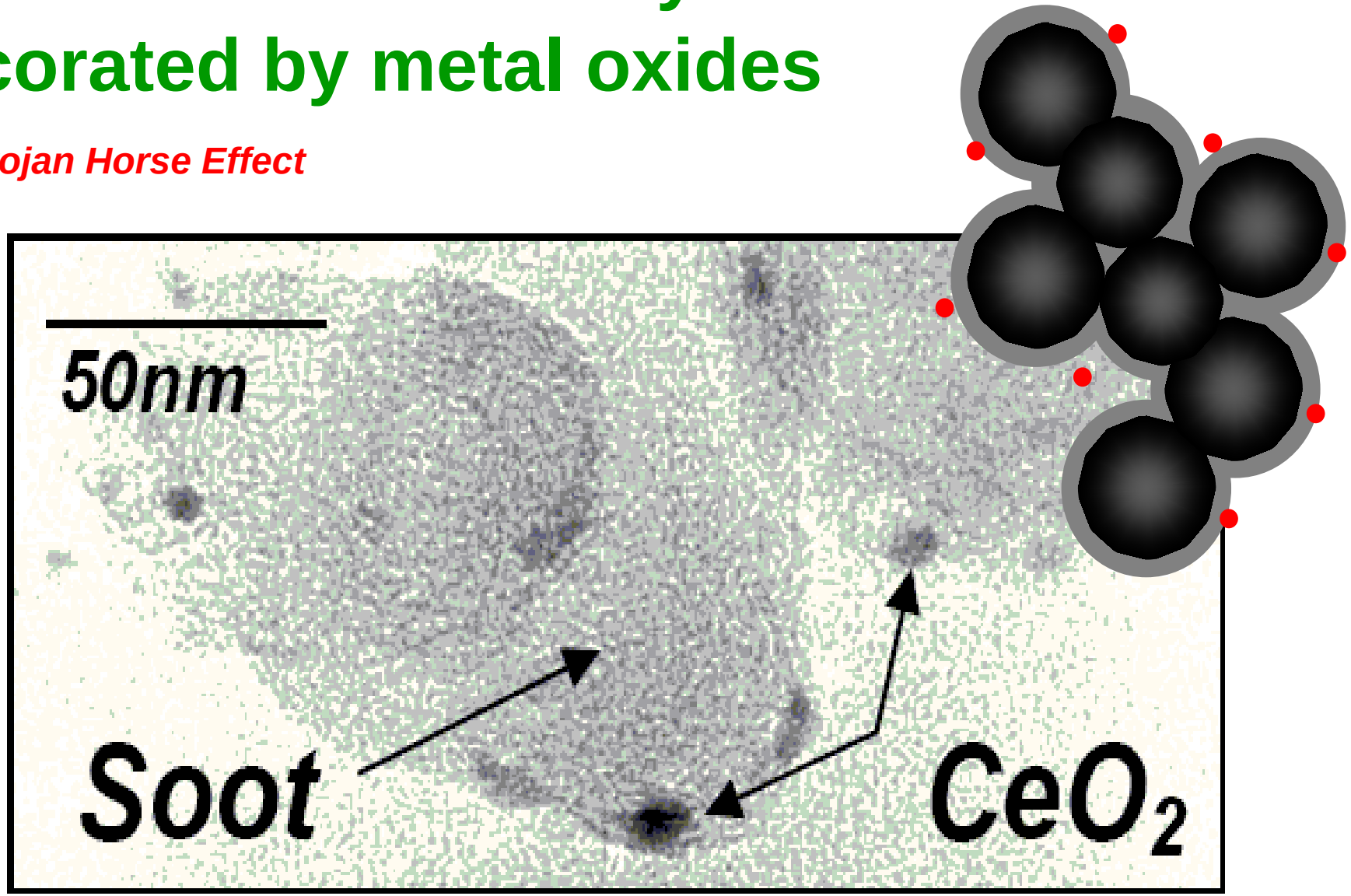
PM2.5 US: 320 µg/m^3
(24h-mean value)

Beijing 2012
PM2.5: 320 µg/m^3
'Very Poor Air Day'
PN 90'000 P/cc

Beijing 2013
PM2.5: 35 µg/m^3
'Very Good Air Day'
?????????
PN >200'000 P/cc

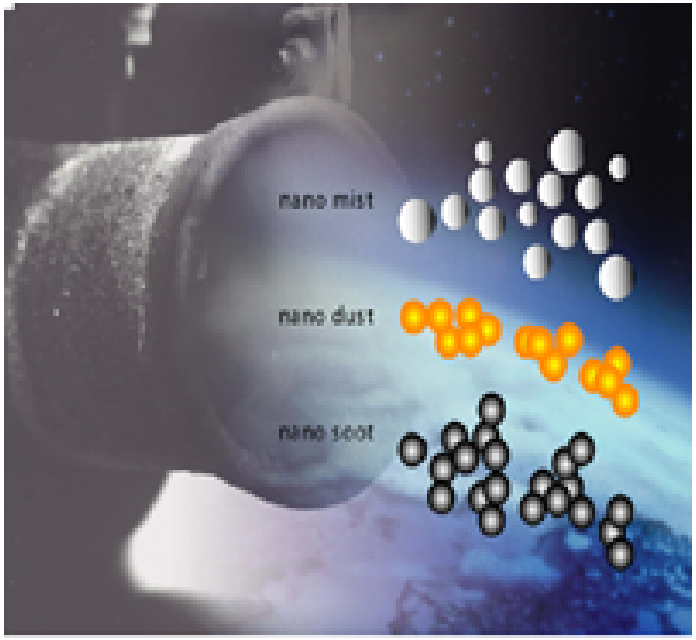
Particles are coated by PAH and decorated by metal oxides

The Trojan Horse Effect



What about metal oxide particles ?

- **Gases**: CO, HC, NOx, SOx
- **Solid soot particles**
- **Metal oxide particles**
- **Volatile particles**

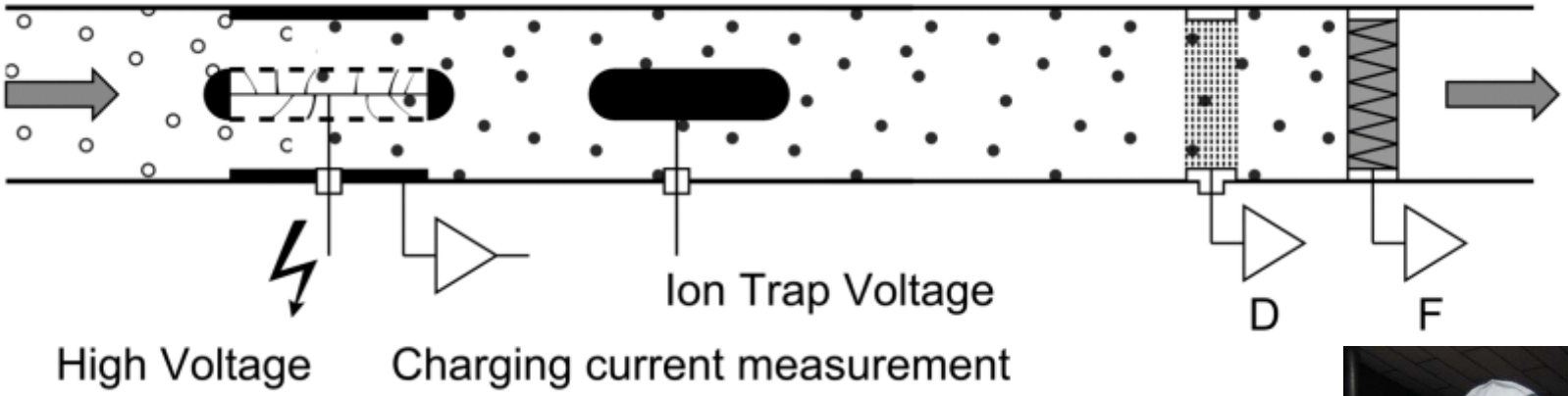


Metal oxides might be the most toxic part. They are very small and their concentration is very high in the exhaust gas of Diesel and Petrol engines

We can not measure them by mass but we can filter them

Diffusion Charging by TESTO and NANEOS

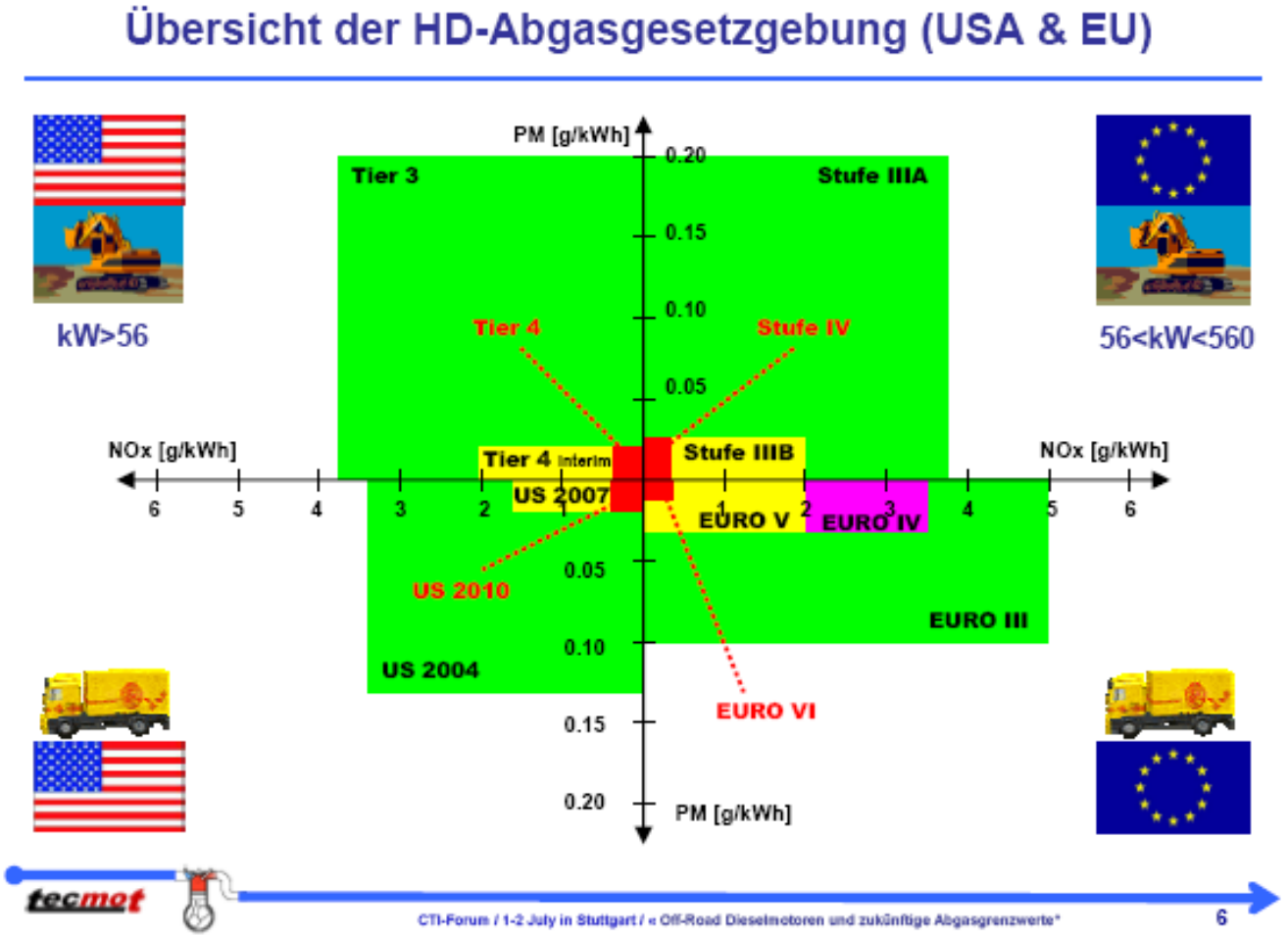
for Laboratory, PEMS, Maintenance and Personal Sampling



Response of International Legislation ?

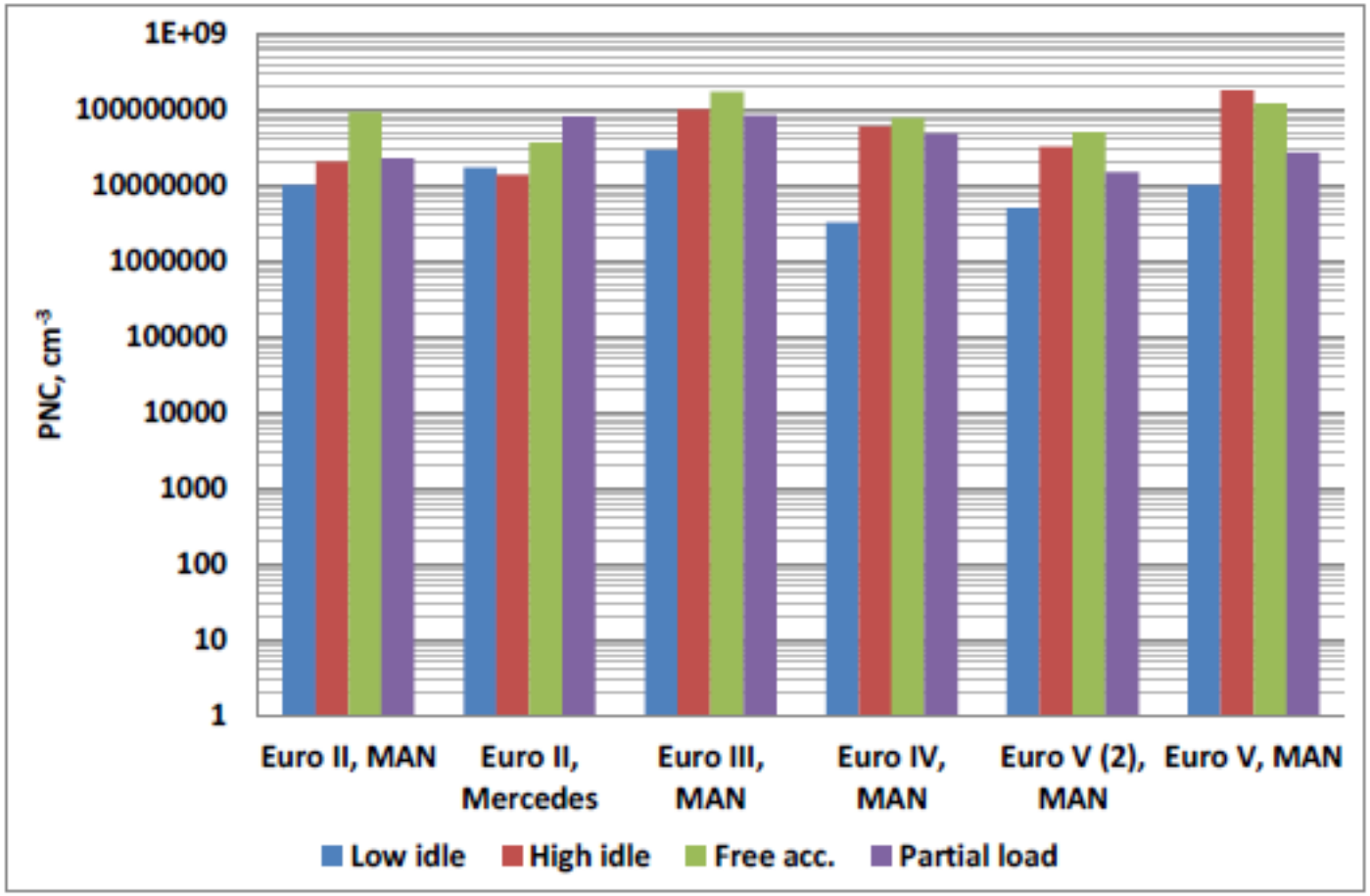
→ Impressive reduction of PM Mass

but is this the solution ?



Nanoparticle number concentrations

Steady-state regimes



Why should we introduce DPF ?

Question of Swiss government 2002

1. because of the health effects of solid nanosize particles at the working place and in the public

2. because of the impact of black carbon nanoparticles on global warming

3. because the Benefit/Cost of DPF is > 10 which means that the society is gaining money by this investment, reducing health cost

Conclusion on European Level

EU CO-Decision (Art.12, Rec.15 - 2008)

- In order to achieve these environmental objectives it is appropriate to indicate that particle number limits are likely to reflect the highest level of performance with particle filters using best available technology

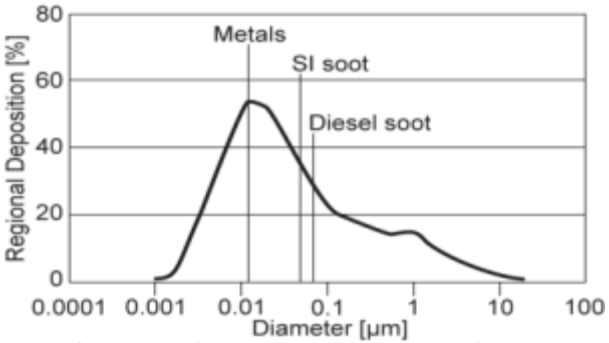
- .. the commission shall introduce particle number based limit values at a level appropriate to the technologies actually being used.

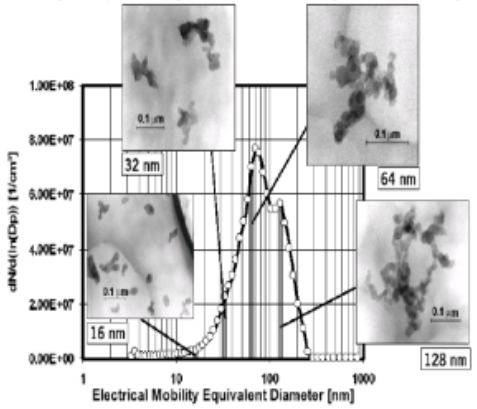
→ 2011/14 Euro VI/6

PN < 0.6x10^{12} P/kWh in addition to 10 mg/kWh (mass DL)

Strange Coincidence

The most sensitive size range of the Lungs
is the most intensive emission range of the Engines





The Lung is an open door for engine emitted ultrafine particles in this size range

Smaller particles are deposited in the upper airways by diffusion, end up in the liquid film which covers the airways and are cleared out,

larger ones are deposited by impaction. Still some ultrafines make their way from the nose through the olfactory nerve into the brain direct as Oberdörster showed.

Messages and Conclusions

1. Particle Mass PM is not sufficient to address health effects
2. PM i**s** not sufficient to define BAT emission control technology for combustion engines
3. PM criteria are misleading filter selection
4. PN instrumentation is available for emission control and ambient monitoring
5. PN is indispensible to link emission to air quality

But even PN may not be sufficient in the long run and should be complemented by information on substance (metals ?)

Black Carbon can not substitute PM nor PN because non-carbon toxics might play a very important role