The Journey of the VERT-Nanoparticle Paradigm to worldwide acceptance

16. VERT Forum, METAS, Bern (CH)

19th. of March 2026

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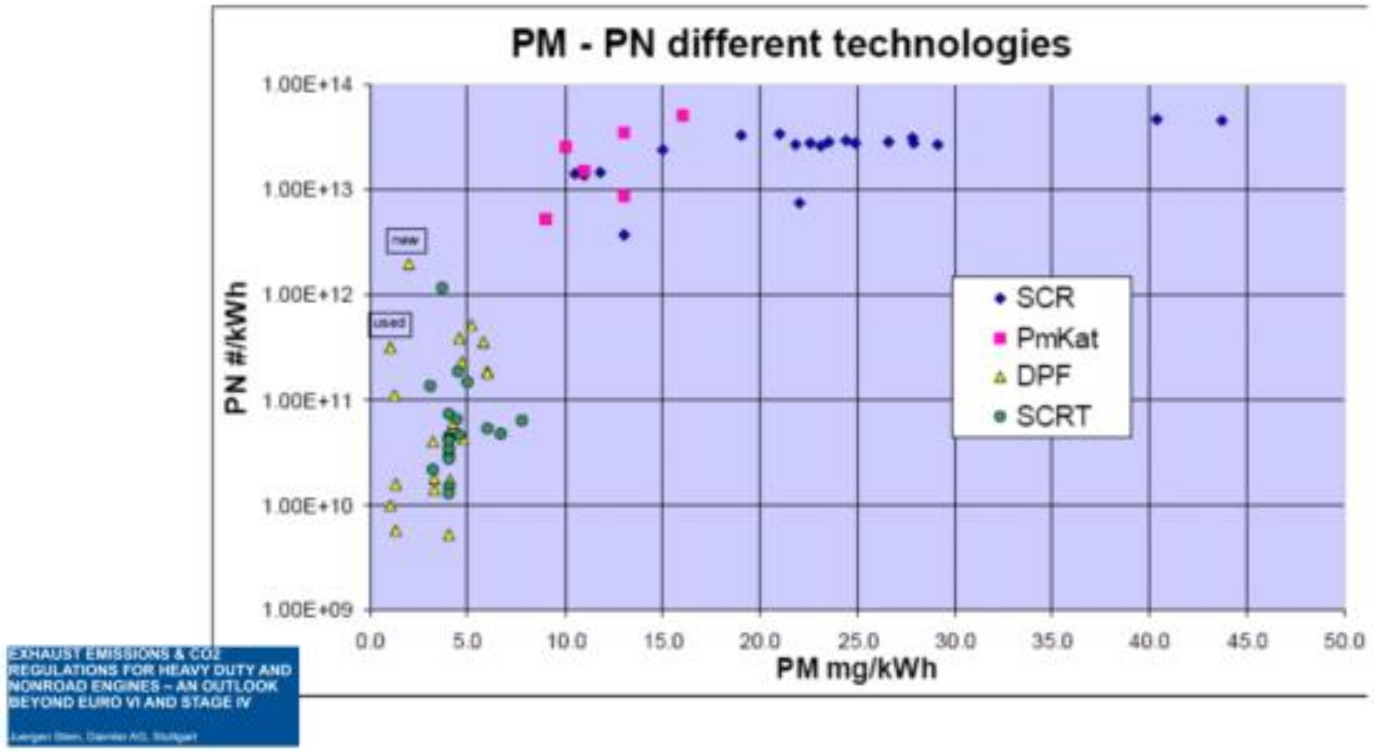
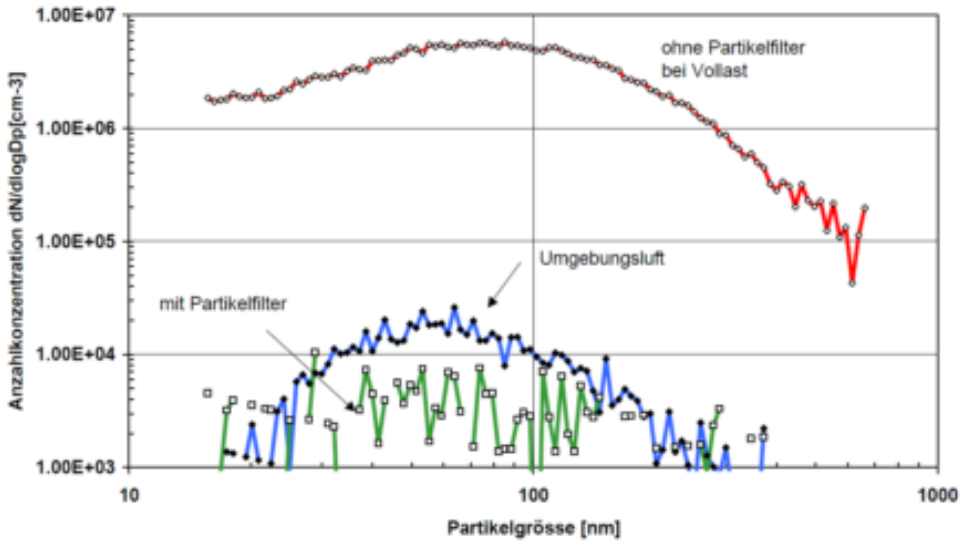
Particle Mass cannot correlate with Number count



In 2010 science have started with analyzing the implications of particle number in conjunction with various exhaust aftertreatment solution

DPF and GPF reduce Heath Effecting Nanoparticles by Three Order of Maginitude

VERT/Matter 1998

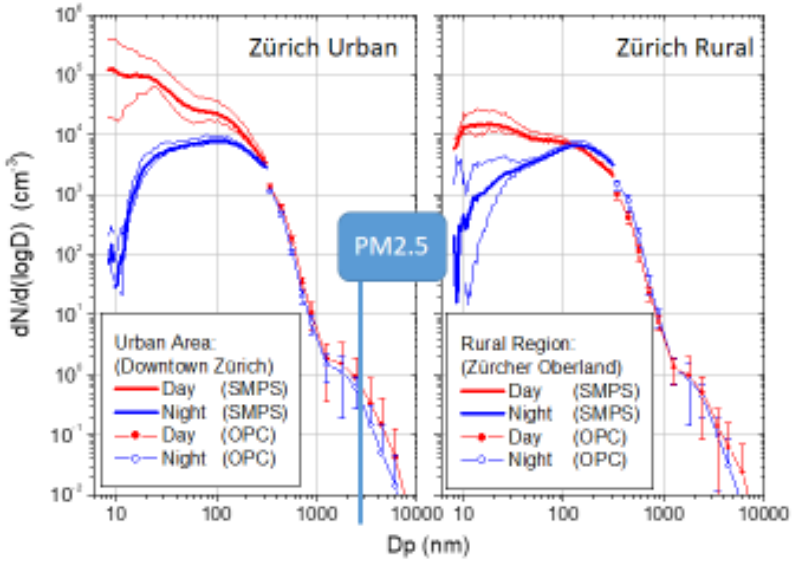


63

Commercially available filter technology actually works for diesel and gasoline engines

PM2.5 is an artefact on a filter but SNP is what we inhale

Aerosol Number/Size – Distribution
City (Zürich) and Coutry (Zürcher Oberland)



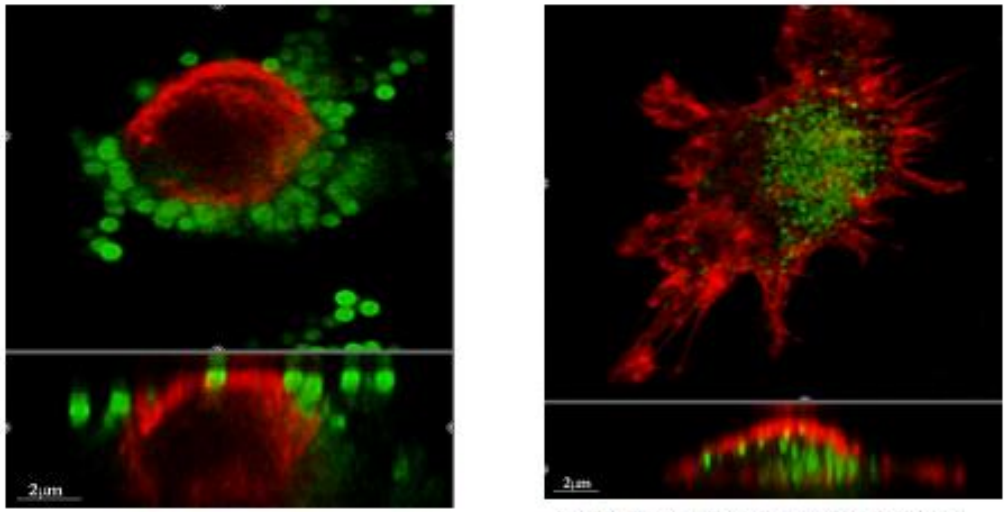
Bukowiecki et al., Atmospheric Environment, 2002

PM2.5 is a filtrate on a filter paper not a an actual pollutant. The figure shows actual particle concentration 5 orders of magnitude smaller in size and equals what is emitted from combustion engines

Particle Size Penetrating Cell Membranes

1000 nm
Polystyrene Particles

78 nm
Polystyrene Particles



Laser Scanning Microscopy

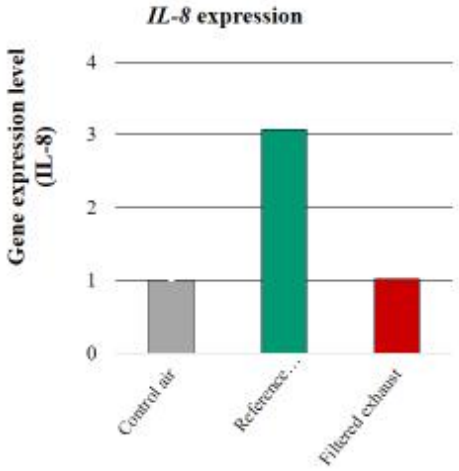
Prof.B. Rothen-Rutishauser, Uni Fribourg
Prof.Peter Gehr, Uni Bern

The smaller the worse

How can we prove that DPF/GPF solves the Health Problem of Engine emitted Solid Particles?

Closest to reality: fresh human lung cells (triple cell model) are directly exposed to conditioned exhaust gas with or without filter at road-typical concentrations.

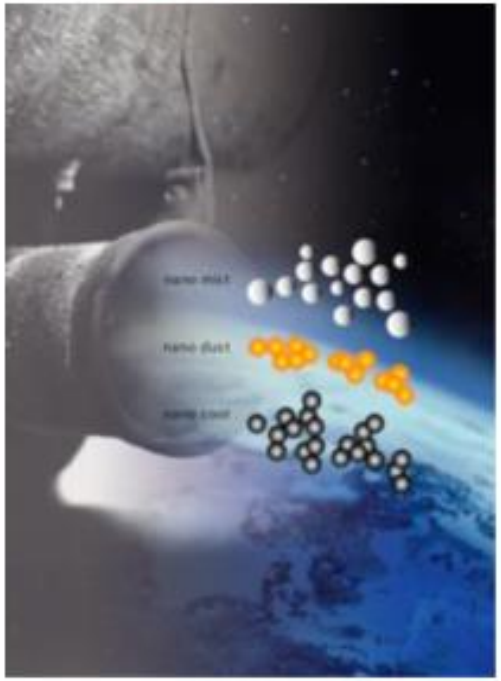
Without filter the cells react within few hours with strong inflammation, which is regarded the start of multiple health effects but with filter no inflammation occures.



The influence of engine exhaust to the living human cell cultures tested for inflamation (IL-8 expression)

VERT TAC Definition: Why Particles and not Gases?

Toxicity of Solid Particles compared to Gases and Volatiles



Gaseous Emissions CO, HC*, NO_2 and Volatiles are not toxic
at urban concentration since once inhaled they are further diluted to molecular level reaching a very low specific dose. They have no mortality effect nor are they carcinogenic.

Solid Nano-Particles are not diluted but only dispersed
They remain to be a compact highly-toxic package including their firmly adsorbed heavy PAH and metal oxides and due to their nanosize they travel as such unchanged (undigested, not metabolized) within two hours to any spot in the organizme including heart, brain, placenta, foetus.

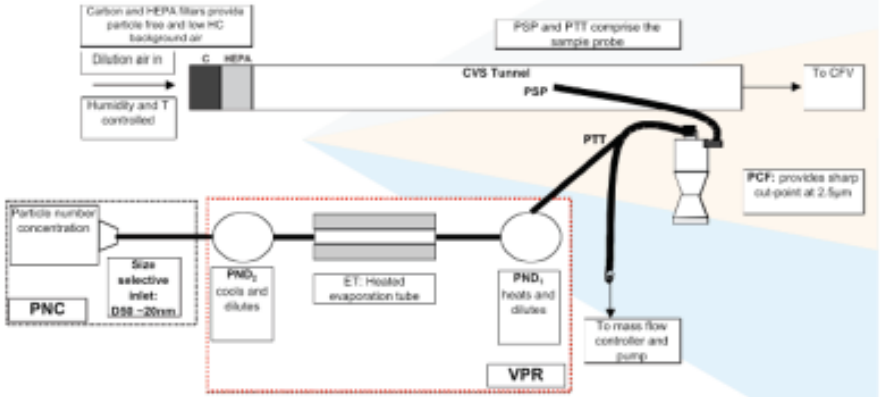
1995: The VERT Definition for lethal toxic air contamination is Solid Particles in the mobility size range of 10 nm to 500 nm. Metrology and Legal Limit Definition must by based on Solid (insoluble) Particle Number Concentration

The five emissions and how to identify; Focus; Particles - adoptation of particle number historically followed 4 steps/approaches

How was the VERT Paradigm implemented in the worldwide emission policy?

2000: The first step; EU adopts the VERT Philosophy in coperation with JRC but the result was rejected by the EU memberstates not accepting this major metrology change from PM to PN

UN-ECE PMP-setup for Particle Number Count for the vehicle Homologation Process



41

2006: The second approach; VERT-definition adopted via UN-ECE in the international PMP defining, selecting and testing instrumentation for solid particle counting. The method is shown above and combines heating and dilution to exclude volatiles (Source: PMP)

2008: The third approach; VERT Philosphy adopted in the Euro VI homologation requirements

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

where 0.6×10^{12} represents only a mass of 0.2 mg/kWh

2014/15: The fourth approach; REC-132 – Eurpoean DPF rettroifitcertification based on VERT filter certification 1997

It is so simple, fast and cost effective
Internation Working Group NPTI 2016

- **PN-Test at low idle**
- PN with DPF; $< 10^3$
- PN with failure $> 10^6$
- Pass/Fail: 100'000 1/cc
- VERT 2012

This Test is more than Pass/Fail

It supplies **quantiative diagnostic** information for the **functionality** of each emission control component and the engine as well and permits **preventive repair and maintenance.**

2016: Fifth approach; Adoptation of th VERT paradigm/philsophy in NPTI

Many NPTI Instruments are now available and certified

FECHA 28/11/2023	APROBACIÓN								
MARCA	NL	CH	D	FABRICANTE	TIPO	DC/CPC	SISTEMA MUESTRAS	RANGO (000#/CM^3)	DILUCIÓN
TSI				TSI	3795 (NPET-l)	CPC	Dilución	5 - 5.000.	10
TSI				TSI	3795 (NPET-h)	CPC	Dilución	50 - 50.000	100
TEN				TEN	AEM	DC	LMC*	5 - 5.000.	1
VLT				TEN	E9700	DC	LMC	5 - 5.000.	1
Saartoox				TEN	DPC	DC	LMC	5 - 5.000.	1
Capelec				Capelec	CAP3070	DC	LMC	5 - 5.000.	1
AVL-DiTest				AVL-DiTest	Counter	DC	LMC	1 - 10.000	1
Continental				Capelec	DX 280 DC	DC	LMC	5 - 5.000.	1
Saxon Junkalor				Saxon Junkalor	500	DC	Non LMC	5 - 5.000.	1
TEXA				TEXA	NP 01	DC	Dilución	5 - 5.000.	?
Mahle				Mahle	PMU 400	CPC	LMC	5 - 5.000.	200
Brainbee				Mahle	PMU-400	CPC	LMC	5 - 5.000.	200
MAHA				AVL-DiTest	MET	DC	LMC	1 - 10.000	1
Bosch				Bosch	BEA 090	CPC	LMC	?	?
Assemblad				Assemblad	PRT 121	DC	Non LMC	5 - 5.000.	1
Hella Gutmann				?	HG4-PCK	DC	LMC	5 - 5.000.	1
WOW				*TEN	WPA	DC	LMC	5 - 5.000	1
Bartec Auto ID				Bartec Auto ID	nEC	DC	LMC	5 - 15.000	1

No technical excuses to void PN measurements in engine exhaust nor in ambient air

WHO Global Air Quality Guidelines 9/2021

after 25 years of PN Standard for Engines
still no equivalent ambient limits
but at least a few comments

Table 0.3. Summary of good practice statements

UFP	1.	Quantify ambient UFP in terms of PNC for a size range with a lower limit of ≤ 10 nm and no restriction on the upper limit.
	2.	Expand the common air quality monitoring strategy by integrating UFP monitoring into the existing air quality monitoring. Include size-segregated real-time PNC measurements at selected air monitoring stations in addition to and simultaneously with other airborne pollutants and characteristics of PM.
	3.	Distinguish between low and high PNC to guide decisions on the priorities of UFP source emission control. Low PNC can be considered < 1 000 particles/cm³ (24-hour mean). High PNC can be considered > 10 000 particles/cm³ (24-hour mean) or 20 000 particles/cm³ (1-hour mean).
	4.	Utilize emerging science and technology to advance approaches to the assessment of exposure to UFP for their application in epidemiological studies and UFP management.

World Health Organization

111

2021: Recent approach: WHO recommended PN measurement

Dissemination & Communication

Much educational material available

www.nanoparticles.ethz.ch

www.vert-certification.eu

www.motorlexicon.de

7 books and > 250 papers

Safety is possible.

Checklist

Particulate filters for diesel engines used underground

VERT Focus Day tomorrow

16th VERT Forum & VERT Focus Day

March 19th-20th 2026 – METAS, Berne

- *IAQ and New Nanoparticle Mitigation Principles*
- *NPTI Review and Mission*

Registration: Details on page 6

Highlights of the 16th VERT® Forum

- **Nanoparticle Pollution Indoor and New Mitigation Pinciples for IAQ**
- **Cleaning breathing air in vehicle cabins**, the highest exposure to carcinogens → filling a high priority occupational health gap
- **Virus protection by cleaning indoor air** (schools and hospitals) from UFP and aggressive bioaerosols like viruses → to reach infection risk reduction of >95%
- **GPF-retrofit within HORIZON Europe AeroSolfd project** → o support EU for 5 Mio retrofits in LEZ 2025
- **NPTI-PN as unique solution** for emission control of not only Diesel but also Petrol engines of any application → to eliminate high emitters, support legislation and go global with new instrumentation

What VERT® stands for

An association dedicated to the promotion of Best Available Technology for emission control and ultrafine and nanoparitcle emissions reduction via filtration means

The core objective of VERT is the minimization of health effects caused by combustion engine emissions, especially the elimination of Ultra Fine Particles (UFP).

Members of VERT are international manufacturers of engines, testing devices, DPF and SCR systems, as well as of substrate producers, chassis builders, among others.

VERT stresses and recommends the application of particle number measurement against a pure particle mass metric. Ultra Fine Particles (UFP) cause a major threat to health.

VERT sets the highest quality standards for emission control technology by certifying emission control technologies and publishing the VERT filter list.

VERT supports traffic pollution reduction programs all over the world, especially in megacities, occupational health and indoor.

Thank you for your attention