The Dirty Tail of Vehicle Fleets and how to Detect and Clean the High Emitters - the Fastest Route to Clean Urban Air at Low Cost

Dr. Lauretta Rubino, T. Lutz, J. Czerwinski, L. Larsen,
H. Burtscher and A. Mayer

VERT Association

27th ETH Nanoparticles Conference June 10-14, 2024, ETH Zurich

AGENDA

- Introduction & Motivation
- VERT & NPTI
- HORIZON AeroSolfd Project
  - NPTI testing campaign
- Summary

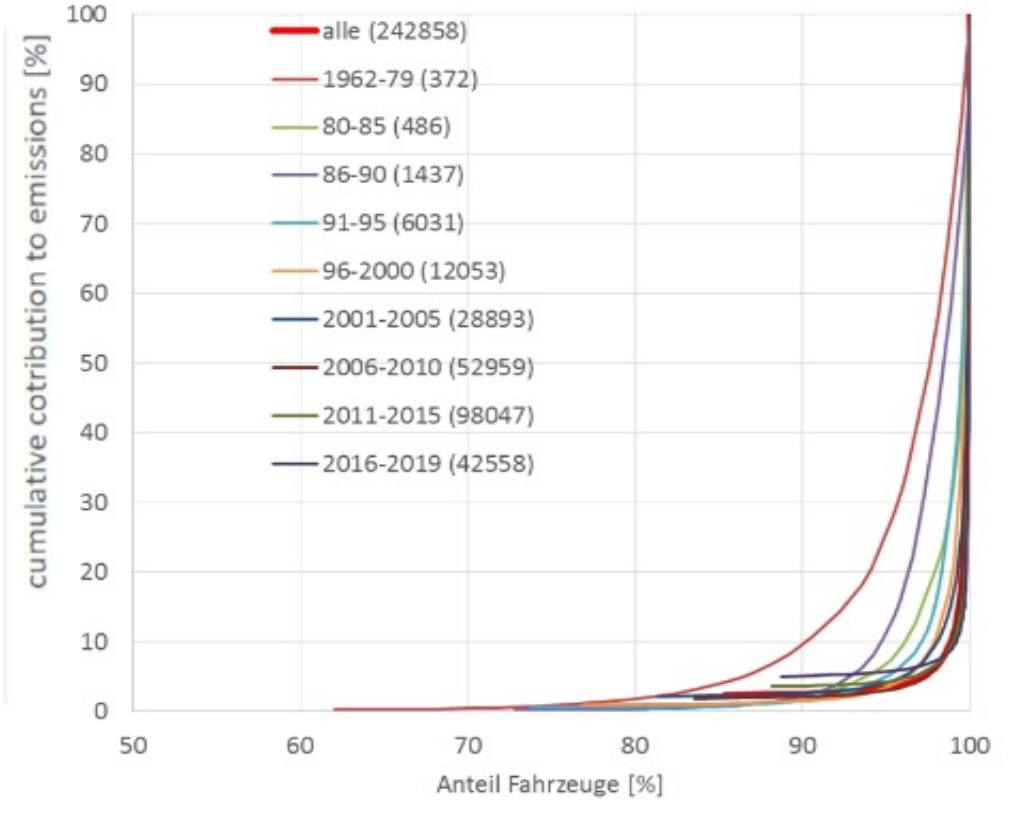
INTRODUCTION

- **Homologation, Conformity of Production (COP), In Service Conformity (ISC) and Surveillance Monitoring** take care of systematic deteriorating effects of emissions given by the applied technology and established production quality
- **In view of the steadily tightening limits** of exhaust gas legislation, which now also includes a PN limit value for all new DI petrol engines in the EU, **it is to be expected that the vast majority of vehicles will comply with the limit values, or even be below them**
- **However, periodic technical inspections (PTI),** which are carefully carried out in many countries, and occasional roadside inspections by remote sensing or plume chasing, **show that a proportion of vehicles exceed the limits by a large margin - How can this be explained?**
- **What about wear, random failures, maintenance negligence and intentional manipulation**, which might have much stronger influence on urban air quality than built-in and well controlled systematic deteriorations?
- **This risk of deterioration in vehicle fleets has become even larger with the introduction of emission control elements like DPF, DOC and SCR** since these technologies are expensive to replace and temptation for manipulation is increasing

VERT & NPTI

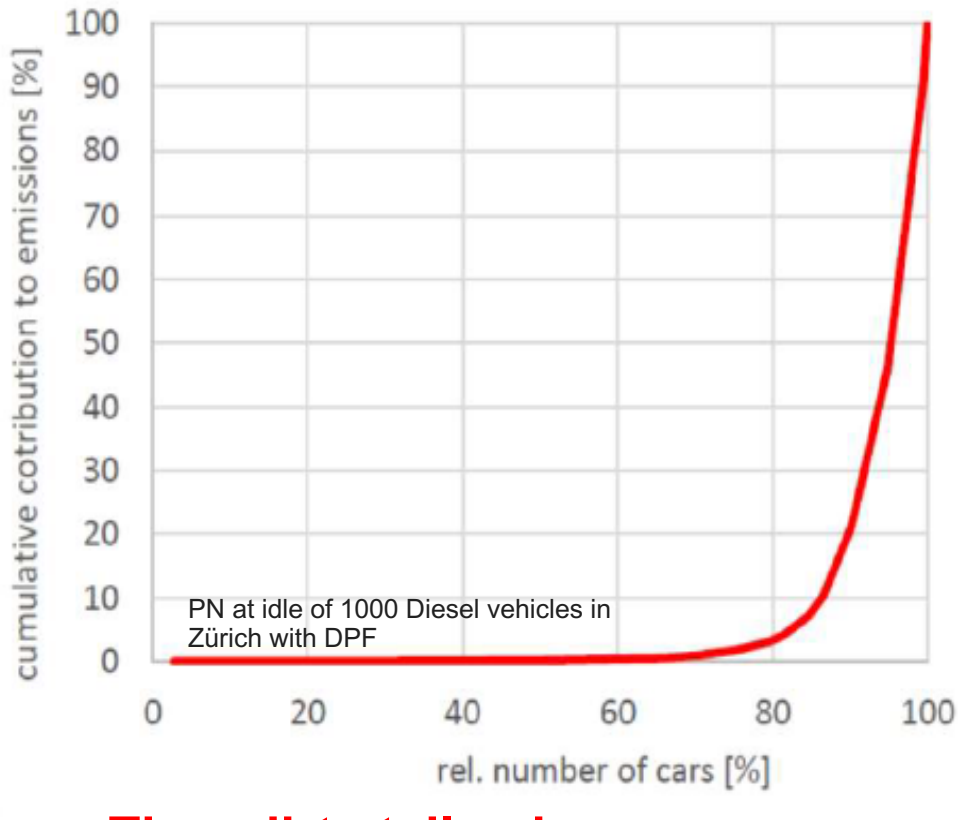
- **VERT has been very active on "New periodic technical inspection" (NPTI)** since 2016, establishing a new test method within the international VERT-NPTI working group (2016-19) now implemented in several European countries for testing of DPF-equipped Diesel vehicles, and collaborating with different policymakers, environmental authorities, type approval authorities, equipment manufacturers and PTI service providers **as well as conducting different case studies**
- **In particular, VERT carried out** with the local authority SEDEMA **a PTI case study with 400,000 in-use gasoline vehicles in Mexico City** (2018); All PTI stations were equipped with roller dynamometers, so that a simplified test could be carried out that reflected the emission behaviour in urban traffic (Dominguez C. / GESPA 2018, JRC No.CTEX2020D380212-101)
- **PTI measurements in Mexico showed that 2-3% of the vehicles are responsible for over 90% of the particulate emissions of the all fleet.** For some generations of vehicles, the effect was even greater and **can dominate the pollution of urban air**
- **The problem is not only in Mexico City, but in many urban areas.** The analysis of 1000 **Diesel vehicles in Zurich showed that 8% of the vehicles** are responsible for **over 90% of the total emissions**

2-8% of the vehicles may produce > 90 % of the overall emission of the fleet



The «dirty tail» phenomenon with Petrol Engines
PN-Emission of 400'000 cars in Mexico City (VERT+Sedema, 2018)

* Source= Dominguez C. / GESPA; 2018; JRC No. CTEX2020D380212-101



The «dirty tail» phenomenon with Diesels <u>with particle filters</u>
Cumulative contribution of High Emitters to Zürich fleet emissions
(Gloor, VERT Forum 2018)

High Emissions because of Petrol Engines

All Megacities have the same pollution problem due to growing size and traffic emissions
VERT is everywhere active to transfer Best Available Tehnology for Health and Global Warming Mitigation

*Source Dr. LRubino et Al. - SAE Paper 2023-24-0114

The "dirty tail" of every vehicle fleet

- **If these "high emitters" could be found and repaired or eliminated, particulate emissions would be reduced to 1/3 in a very inexpensive and quick action.** There is no other, more cost-effective method to reduce particulate emissions in a city so massively in such a short time
- **The causes for this phenomenon of "high emitters" are different and mostly stochastic in nature**:
  - Statistical error distributions in materials
  - Tolerance outliers, unexpected operating conditions
  - Non-standard fuels and lubricating oils
  - Overloading, lack of maintenance
  - Use of cheap spare parts
  - Manipulation, mostly for cost reasons
  - engine, turbo and aftertreatment (i.e. DOC/TWC/ SCR / DPF/GPF) malfunctions
  - ….

The "dirty tail" of every vehicle fleet

Just a few examples, which deserve more research to understand the technical reasons of the “dirty tail” in details:

- **Injection problems** ⇒ **PN**
- **Turbocharger problem** ⇒ **PN**
- **Valve leakage** ⇒ **PN**
- **Altitude compensation problem** ⇒ **PN**
- **Fuel problems / Lube Oil quality** ⇒ **PN**
- **EGR-Problems** ⇒ **PN**
- **DPF/ GPF-Problem** ⇒ **PN**
- **Piston, liner or ring wear** ⇒ **PN**
- **DOC and SCR-problems** ⇒ **PN**

Why choose PN?

PN is the best flagship metric for air pollution because:

- **it dominates the health risk in urban air**
- **It is the most sensitive criterion**, easy to control, monitor and quantify
- **it best characterizes the main contributor of the internal combustion engine (both Diesel & Petrol)**

➢ **The target is to use this tool for all vehicles and also to find out which technical measures can be recommended to mitigate the "high emitters"**

➢ **Preliminary data over 600 gasoline vehicles** from a NPTI testing campaign of 1000 gasoline, including GDI with no GPF, PFI and GPF-equipped vehicles, within the **Horizon Europe AeroSolfd project** are presented. Further data analysis is ongoing

➢ **These preliminary data show a "dirty-tail phenomena"** that needs attention and mitigation measures

The "dirty tail" of every vehicle fleet

- **VERT within the HORIZON Europe AeroSolfd project** has recently established another international expert group to study the possibilities of a modern periodic control for petrol engines

- **NPTI testing campaign of 1000 vehicles is ongoing as part of the AeroSolfd** project to test the best procedure to ensure the quality of emission reduction by retrofitting GPF

- **AVLdiTest, BFH and TCS** (Touring Club Switzerland) are our partners in this investigation

- **Preliminary data** (over 600 gasoline vehicles tested) **show the "dirty tail phenomena"** in the gasoline vehicle fleet

NPTI Testing Campaign – 1000 Gasoline Vehicles

AeroSolfd
filtration devices

Test procedure

- Measurement 1 (high idle) **without load**
  - Engine speed between 2000 – 3000 U/min
  - 15 s stabilization, 15 s measurement
  - Record mean value
- Measurement 2 (high idle) **with load**
  - A/C (air conditioning) max + rear window heating
- Engine speed between 2000 – 3000 U/min
  - 15 s stabilization, 15 s measurement
  - Record mean value

Measurements carried out by TCS in Switzerland
In collaboration with AVLdiTest & BFH

Measurement Equipment

- **AVL DiTEST Standalone Counter**

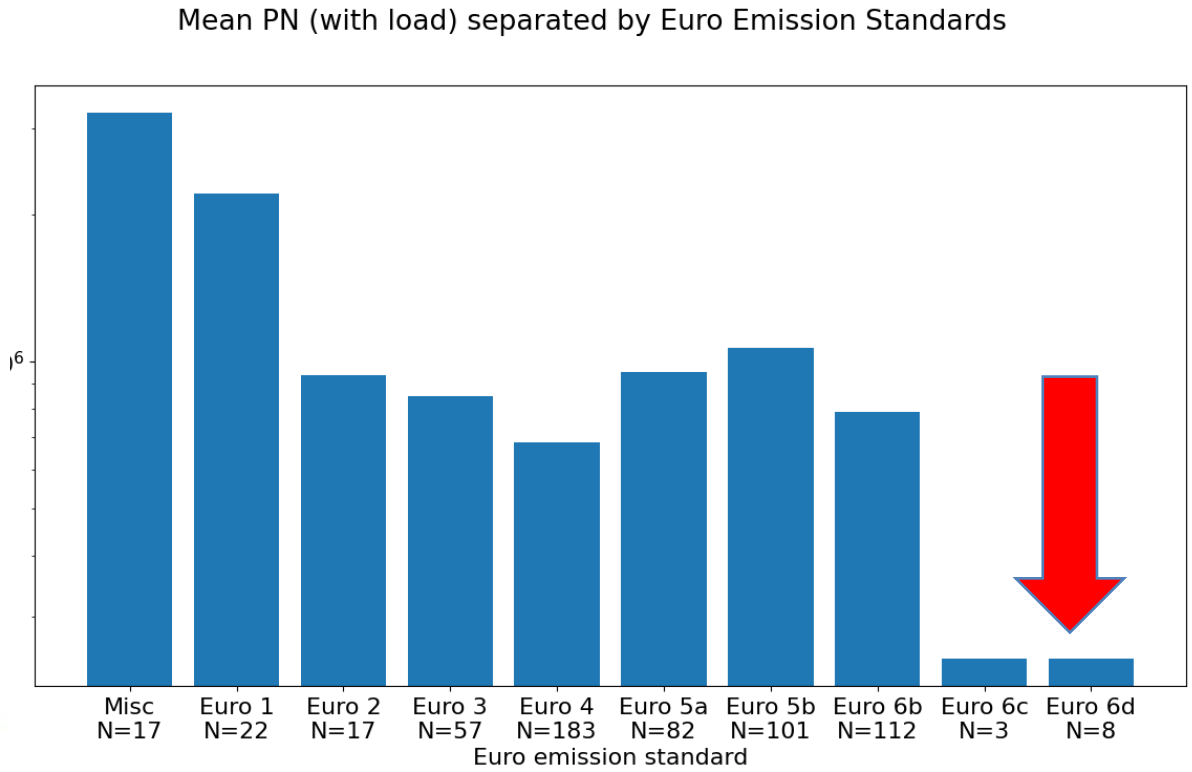
- Based on advanced diffusion charging principle
- With unheated measurement probe
- With water trap
- 23 nm cut-off

Co-funded by the European Union

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

NPTI Testing Campaign – 1000 Gasoline Vehicles

- **Fleet tested:** Different in-use gasoline vehicles, including GDI, PFI and GPF-equipped vehicles

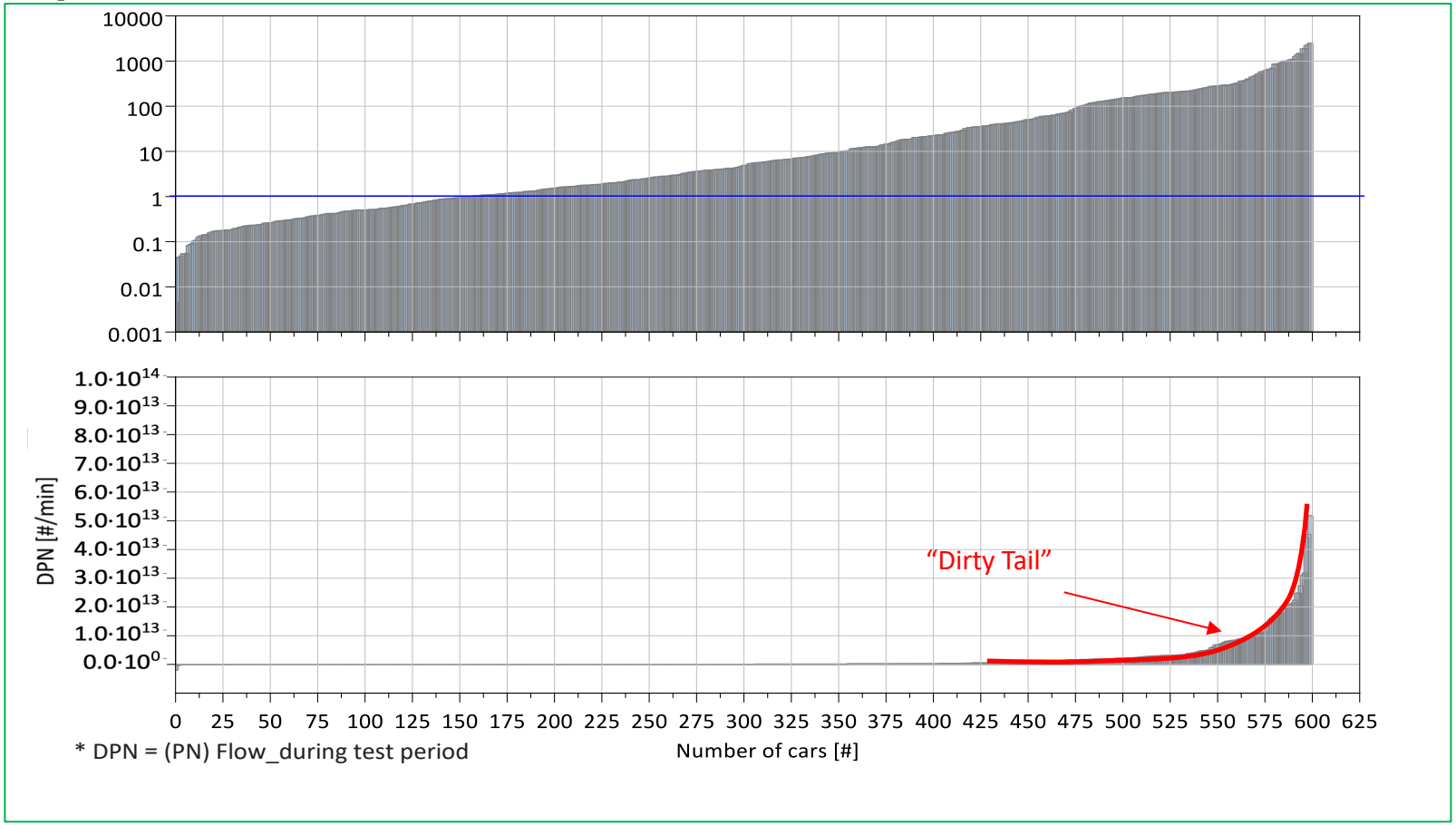


Euro 6d vehicles have significantly lower PN emissions (vehicles with GPF)

Co-funded by the European Union
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

NPTI Testing Campaign – 1000 Gasoline Vehicles

- **Over 600 gasoline vehicles tested** so far for PN emissions
- Preliminary data analysis show good repetability
- **„dirty tail phenomena**“ observed



How to solve the problem?

- **Identifying and removing from the road "high emitters"** will result in an important reduction of the contribution of on-road transport to the total particle emissions and **above all in urban areas**
- **The New NPTI Investigation of 1000 gasoline vehicles** including **DI, PFI and GPF-equipped** vehicles **within the Horizon AeroSolfd** project is an important contribution **to analyse and identify the root-cause of "high emitters"** in urban areas
- **The "dirty tail" phenomena observed** in the in-use gasoline fleet (over 600 vehicles tested so far) **needs attention and mitigation measures**
- **Further data analysis on NPTI testing is ongoing**
- **"New VERT Project" Proposal launched to EU Com & JRC**

Co-funded by the European Union
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

SUMMARY

- **The New NPTI Investigation of 1000 gasoline vehicles** including DI, PFI and GPF-equipped vehicles **within the Horizon AeroSolfd project is an important contribution** to analyse and identify the root-cause of **"high emitters"** and **the "dirty tail" phenomena of gasoline vehicle fleets in urban areas**
- **The "dirty tail" phenomena observed in the in-use gasoline fleet** (over 600 vehicles so far) **needs attention and mitigation measures**
- **More research is needed to understand the technical reasons of the "dirty tail" of vehicle fleets** in details to control emissions – "**New VERT Project" Proposal** to EU COM / JRC
- **The AeroSolfd project, with GPF-retrofit** of gasoline vehicles **aims to a widespread introduction of GPF to reduce nanoparticle emissions** from high mileage vehicles, and will also serve as a platform to **continue research on PN & secondary emissions** from both **DI and PFI engines**
- **The very likely "still presence" of gasoline vehicles until 2035** & beyond **justify the need of GPF retrofit** and **mitigation measures for the "dirty tail phenomena" of vehicle fleets as fast solution to cleaner mobility**

THANK YOU FOR YOUR ATTENTION!

aerosolfd-project.eu

https://www.vert-dpf.eu/

Questions?

Lauretta.Rubino@vert-dpf.eu

VERT project proposal for failure diagnosis when limit values are exceeded in the NPTI

A step-by-step process is planned:

- In a large motor vehicle checkpoint (e.g. Zurich Albisgütli), rejected vehicles are pre-sorted so that the entire fleet is recorded step by step in proportion to its composition.

- The owner of the vehicle requiring repairs is officially requested to make his vehicle available for 2-3 days for this inspection. They will receive a replacement vehicle. We assume that 10% of vehicle owners will accept the offer because they expect it to reduce the repair costs.

- A team of 3-4 trained and experienced vehicle emissions experts (in Switzerland, the Biel-Nidau emissions testing center) will thoroughly test the vehicle according to a standard procedure that has yet to be developed, and may even carry out repairs.

- **After a preliminary phase to develop the test procedure**, this team of experts should become so efficient that 200-250 tests can be carried out in a year.

- **It can be assumed that at least 500 tests will be carried** out in order to be able to draw reliable conclusions from the variety of findings.

- **Vehicle manufacturers / importers and, if necessary, component suppliers** should be involved in these investigations. it must be ensured that the results can be made available to the vehicle industry in full transparency.