PHYSICAL AND CELL TOXICITY PROPERTIES OF EURO 6D DIESEL VEHICLE PARTICLE EMISSIONS WITH AND WITHOUT DPF REGENERATION

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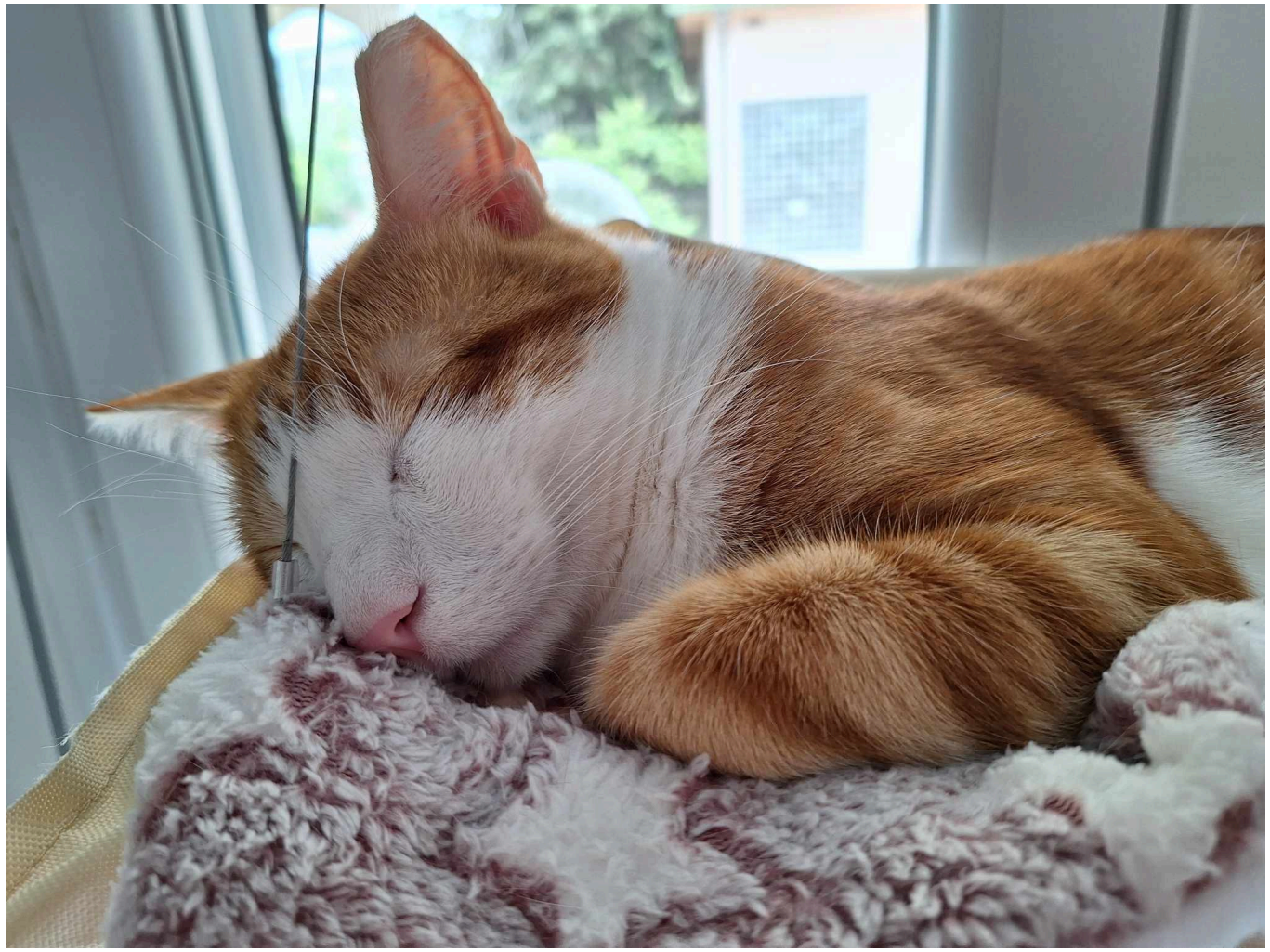
LABORATORY OF APPLIED THERMODYNAMICS




Ok, I’m listening!

Research Objectives

Despite their infrequent and short-lasting nature, Diesel Particulate Filter (DPF) regeneration events can produce a disproportionate amount of particle emissions, which have critical implications for air quality and public health.

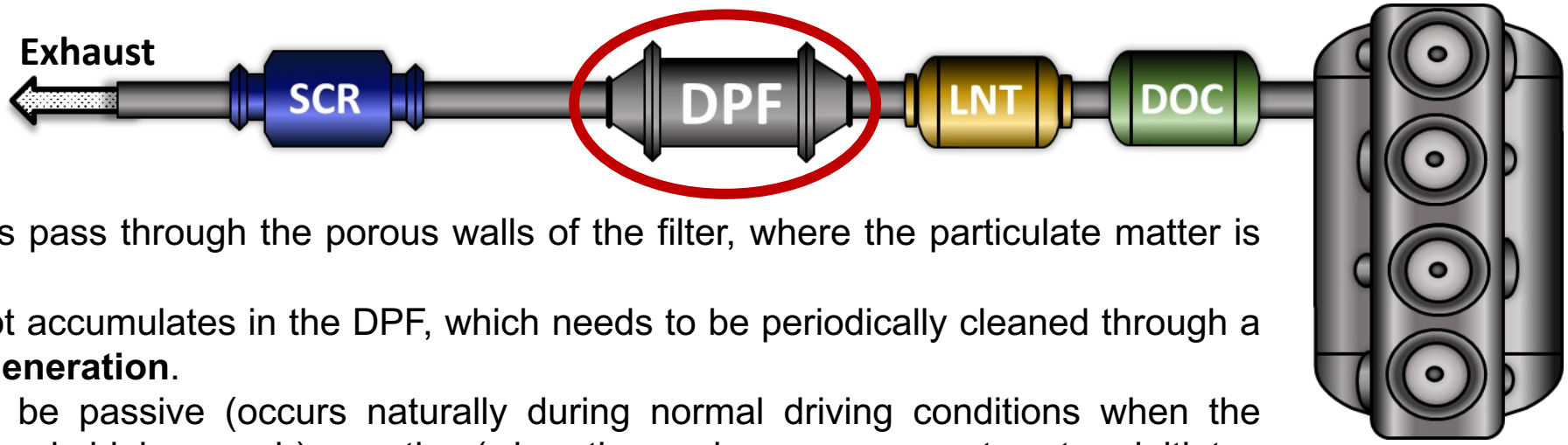
The objectives of this research are:

- Assess DPF Regeneration Frequency and Duration
- Investigate Impact on Particulate Number (PN) Emissions
- Analyze Particle Size Distribution and Nanoparticle Levels
- Evaluate Toxicological Effects of Emissions

Agenda

- Introduction
  - DPF Regeneration
- Methodology
  - Experimental plan
  - The Laboratory
  - Measurement Setup
  - Cell Exposure - ALI System
- Results
  - Gaseous Emissions
  - Particulate Emissions
  - Dosing
  - Toxicity assessment
- Conclusions

Diesel Particle Filter (DPF)



How it works:

- The exhaust gases pass through the porous walls of the filter, where the particulate matter is trapped.
- Over time, the soot accumulates in the DPF, which needs to be periodically cleaned through a process called **regeneration**.
- Regeneration can be passive (occurs naturally during normal driving conditions when the exhaust temperature is high enough) or active (when the engine management system initiates a process to increase the exhaust temperature to burn off the soot).

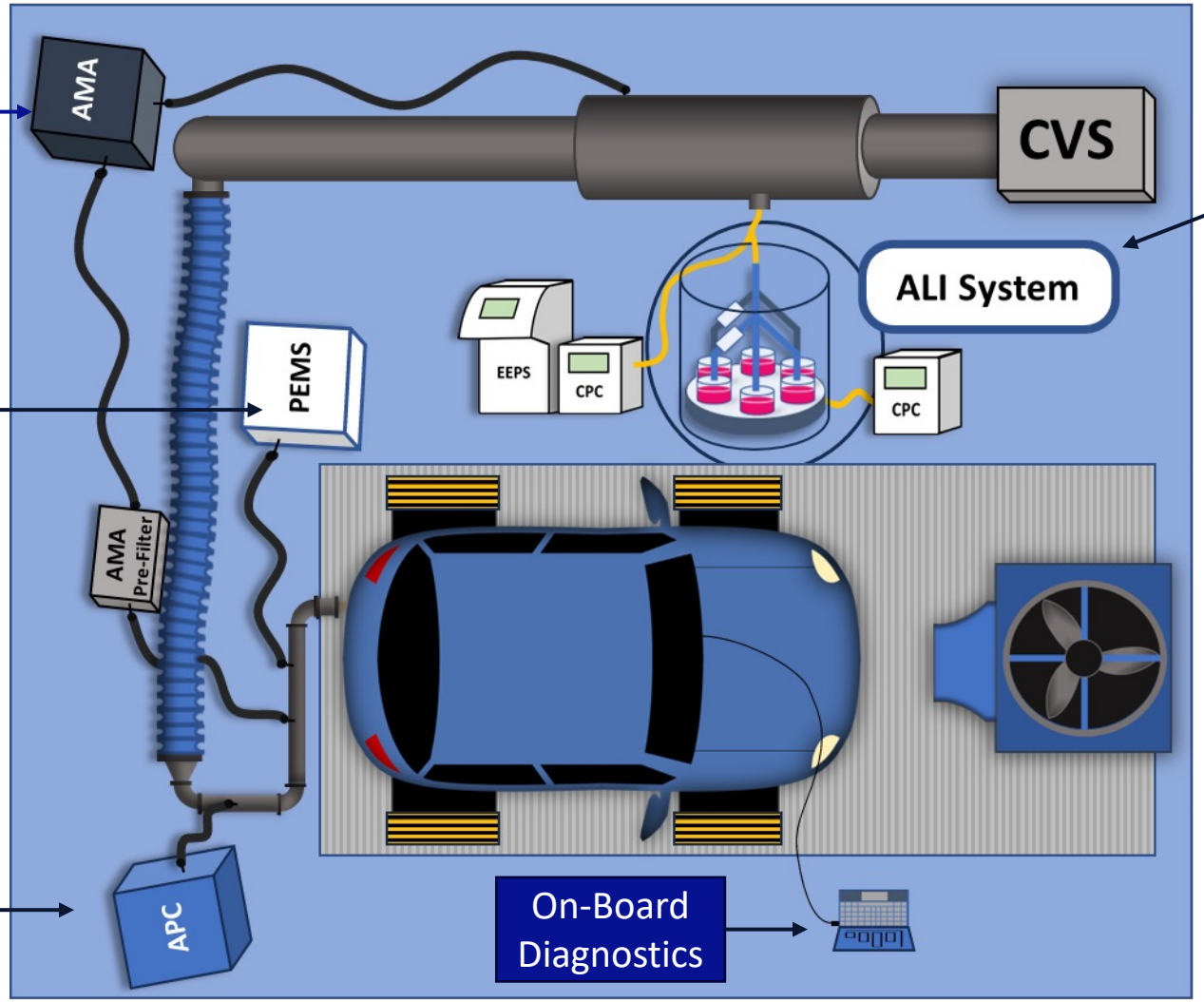
Our Vehicle	
Fuel	Diesel
Engine	1598 CC/ 85kW
Gearbox	Manual/ 6 gears
Emission standards	Euro 6d
Aftertreatment system	DOC/**DPF**/LNT/SCR
Model Year	2021
Mileage	48000

Experiment explanation

Gaseous emission measurement: CO, NOx, THC, CH_4 + CO_2

Solid Particles with cut-off size 23nm (SPN23) + Gaseous emissions verification

Solid Particles with cut-off size 10nm (SPN10)



Toxicological characterization (ALI exposures)

+

- Dosing calculation
- Total (Solid + Volatile) Particles with cut-off size 10nm (TPN23)
- Particle size distribution

- 4 different driving patterns including **RDE**
- More than **4500km** in Chassis dyno
- **12** active regeneration recorded
- 16 2-h **real time cell exposures** 8 w/ regeneration +8 w/o regeneration)

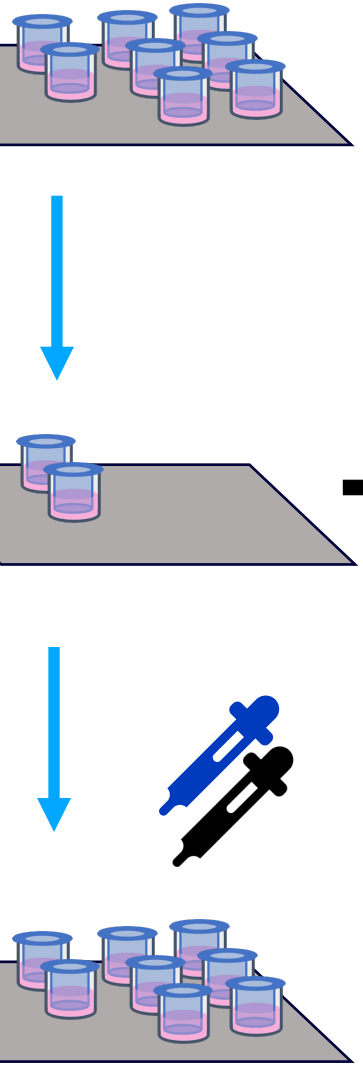
The Laboratory

CVS

Chassis dynamometer

ALI system

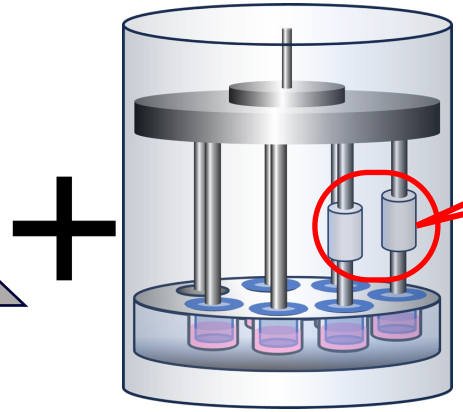
Air Liquid Interface



CULTURE

A549 human epithelial adenocarcinoma cells were cultured until 80% confluency and then recultivated in a concentration of $2x10^5$ cells/well and cultured for 24h

8 Wells - 24h - Cells in incubation (full medium)



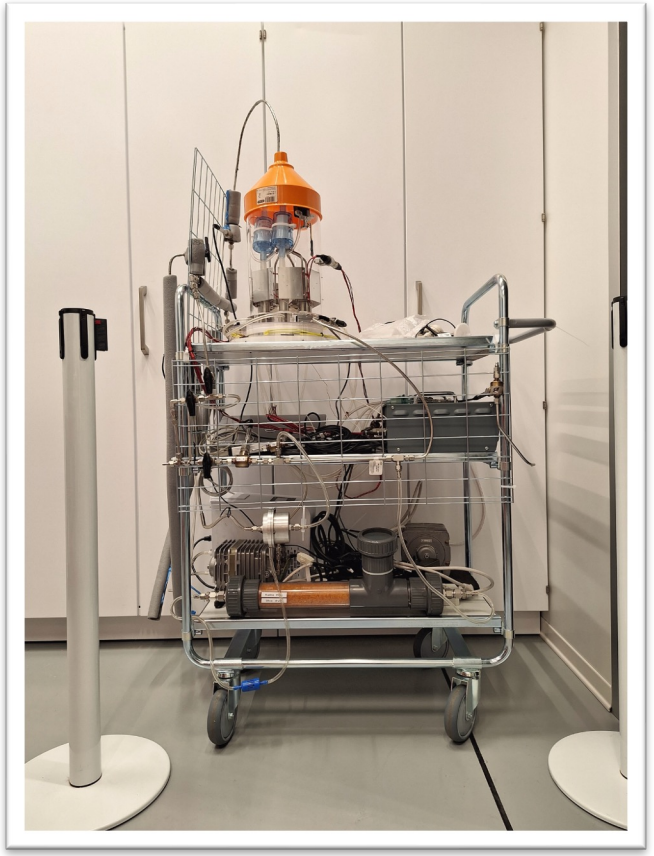
2 HEPA filters to remove the particles

EXPOSURE

2 remain in incubation (control)

2 are exposed in filtered sample (no particles effect)

4 are exposed in non-filtered sample (particle effect)



Inflammation estimation

LDH (cell viability)

IL1β, TNFα (cell stress)

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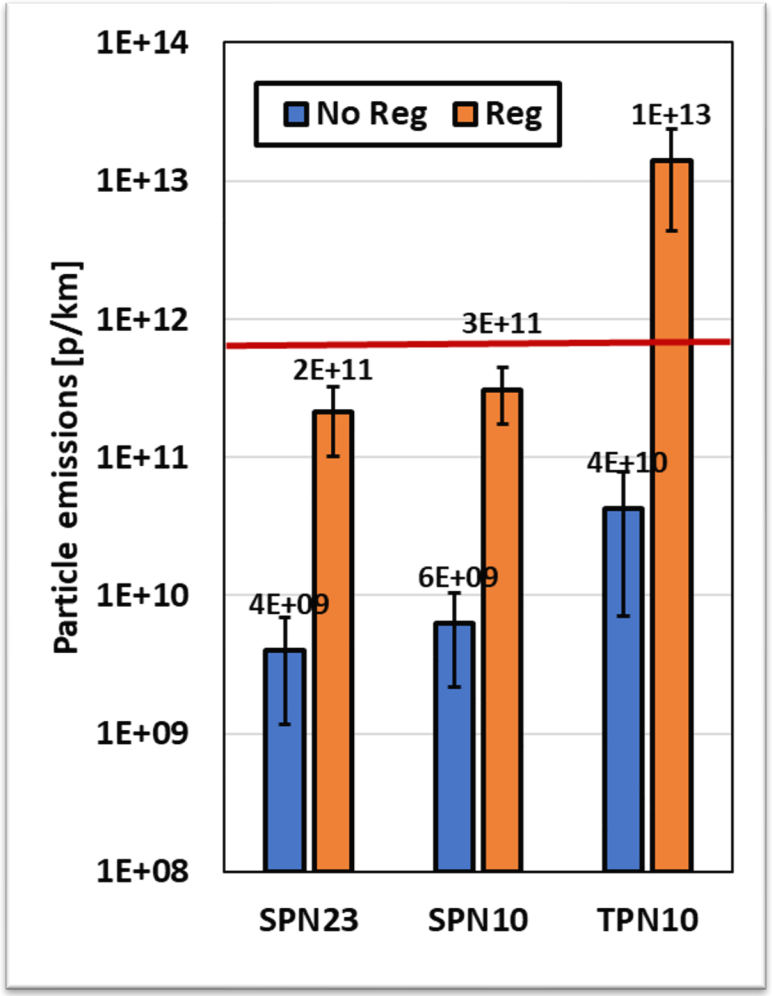
Cytotoxicity estimation

Incubation overnight

Alamar Blue (cell viability)

Vehicle Emission Levels



- **Average Distance** between DPF active regenerations: ~ **415 km** (Std 19 km) and **duration 21-30 mins**
- At least **2 orders** of magnitude more emissions levels during 2h-driving cycles when regenerations is included
- The **Euro 6 standard*** is not surpassed even when the regenerations is included.
- A significant release of **volatile** particles occurs during DPF regeneration
- All other emissions increase during regeneration too (slightly but significantly)

	THC	CH4	NOX	NO	CO	CO2
	mg/km	mg/km	mg/km	mg/km	mg/km	g/km
w/o Regen	17	16	118	93	26	144
w/ Regen	28	29	123	95	38	150
Euro 6 limit	-	-	80	-	500	-

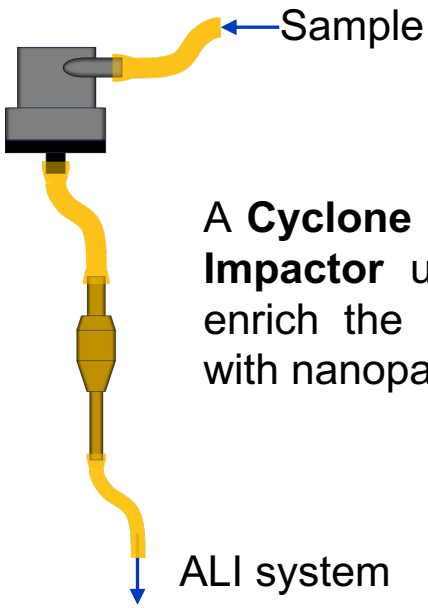
Euro 6 standard: The legislation sets a limit for diesel and gasoline direct injection (GDI), vehicle under the Worldwide Harmonized Light Vehicles Test Procedure (WLTP).
For particle, this limit is 6.0 × 10^11 particles/km for solid particles with cut-off size of 23nm (SPN23)

Particle size distribution and dosing

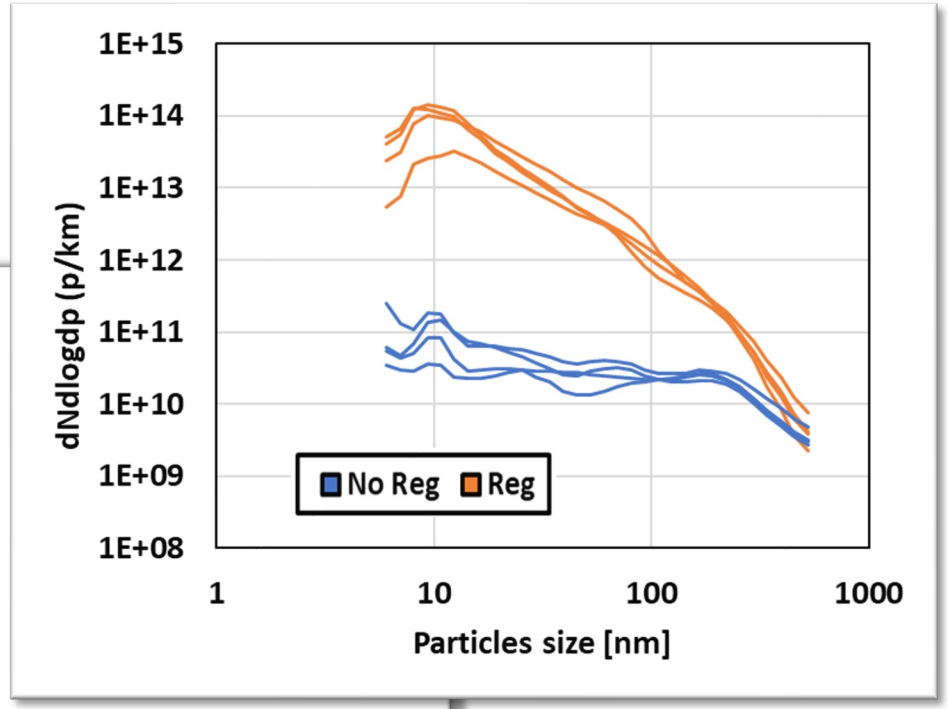
The **mass deposited in the cells** increases by an average of **15 times** during regeneration cycles

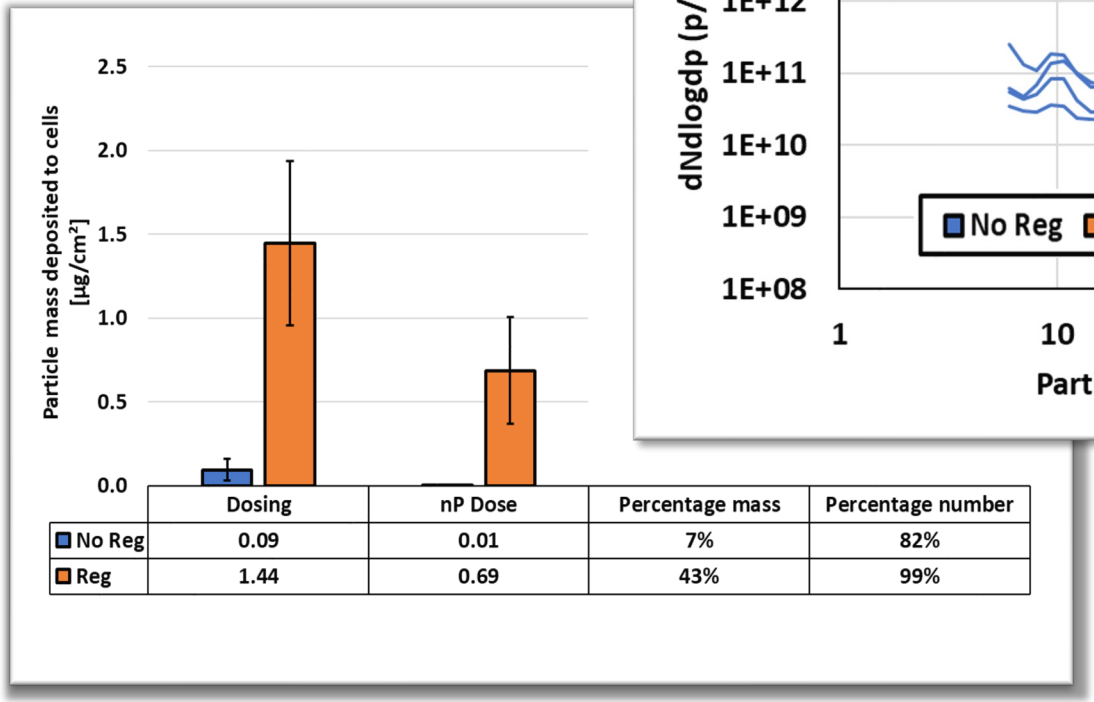
During regeneration, the **presence of nanoparticles** becomes more pronounced:

- Their **proportion** in the mixture increases significantly.
- Both the **number and mass** of nanoparticles rise substantially.



A **Cyclone** and an **Impactor** used to enrich the sample with nanoparticles





	Dosing	nP Dose	Percentage mass	Percentage number
No Reg	0.09	0.01	7%	82%
Reg	1.44	0.69	43%	99%

Cytotoxicity: Cell Viability

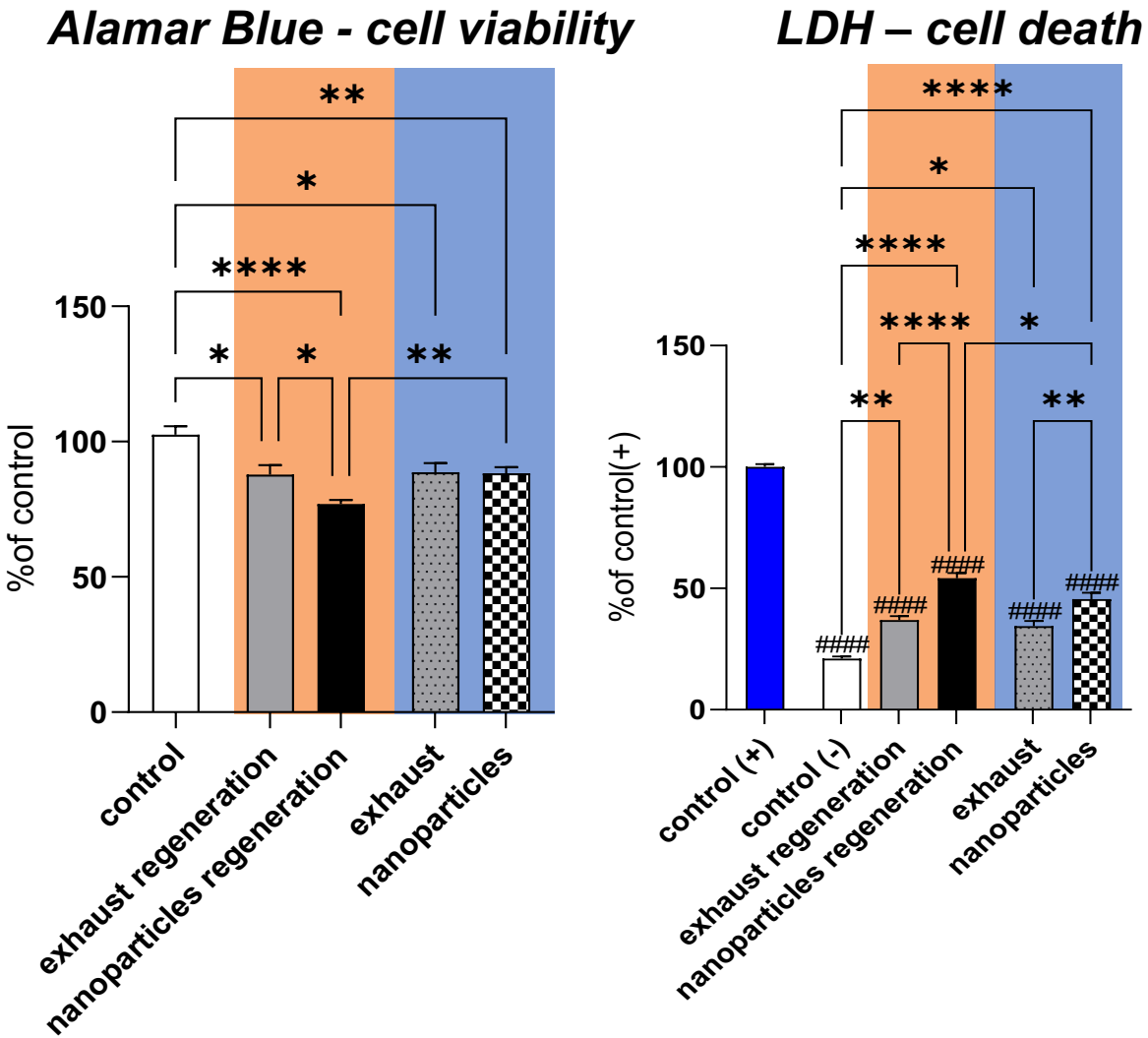
- Gaseous emission reduces cell viability
- Regeneration nanoparticles further reduce viability

Alamar Blue:

*p<0,05
**p<0,01
****p<0,0001
One way ANOVA

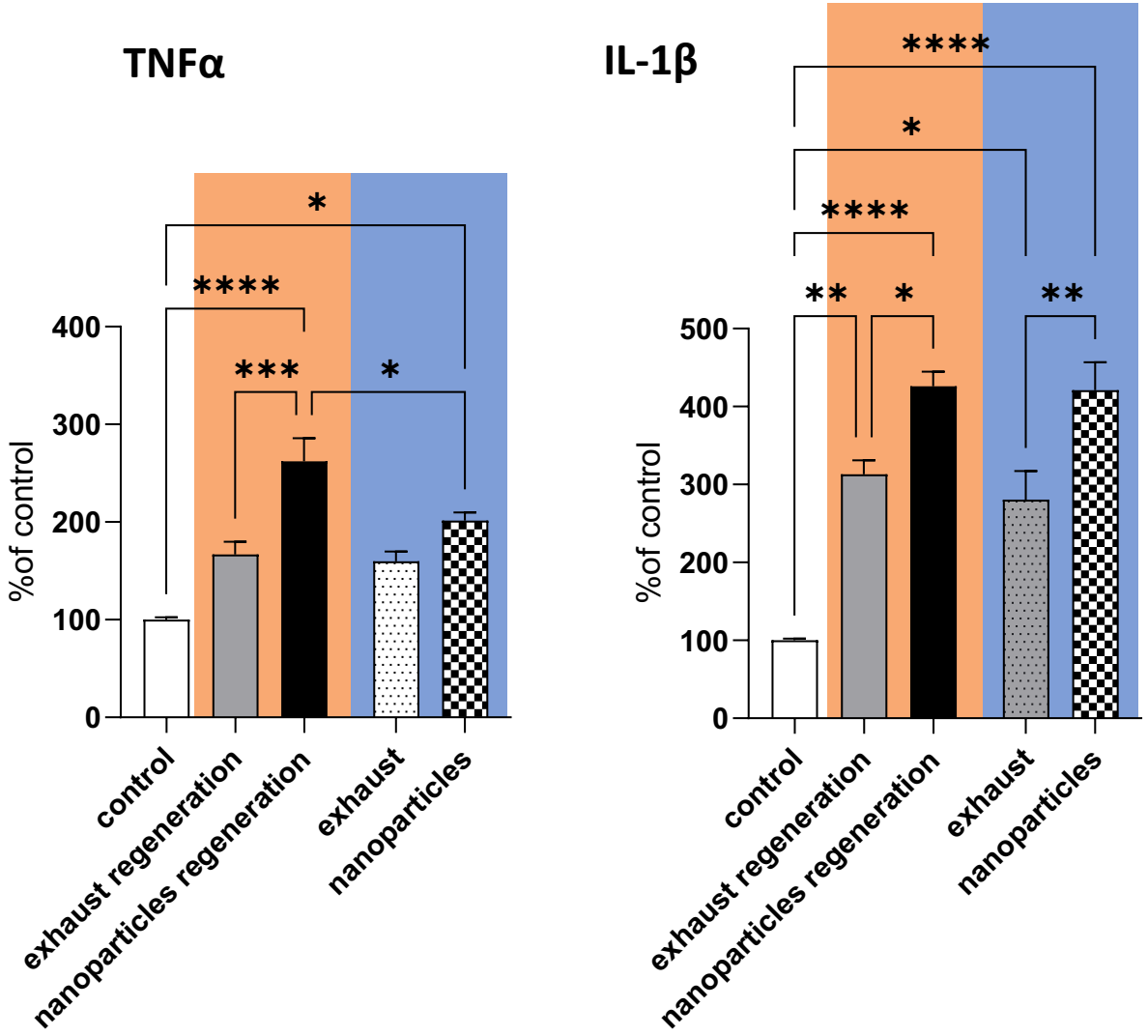
LDH:

####p<0,0001 compared to control (+)
*p<0,05
**p<0,01
****p<0,0001
One way ANOVA



Cytotoxicity: Cell stress (*Inflammation)*

- Gaseous emission increases cytokine production
  - *p -***p, compared to control
- **Particles further increase cell stress**
  - *p -***p, nanoparticles vs gaseous emission
- **The regeneration increase cell stress**

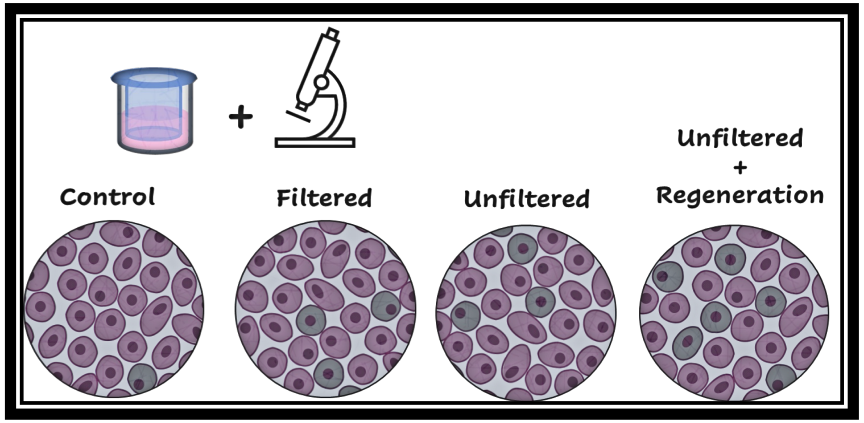


Conclusions

Particle emissions:
The vehicle is a **low emitter**. However, during **DPF regeneration events**, can generate significant amounts of **solid** and **volatile** particle, up to **three orders** of magnitude higher.

Viability Reduction and Emissions:
Reduced cell viability is observed only due to gaseous emissions, not particles, during normal DPF operation. However, particles **generated during** regeneration also reduce cell viability, indicating a **potential threat** to human health.

Cell stress (Cytokine Production):
Both gaseous emissions and particles increase cytokine production, with the effect being more noticeable during regeneration, supporting our previous findings.



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Please contact us for your virtual participation through: https://www.npets-project.eu/index.php/contact/

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