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Are GDI vehicle exhaust genotoxic like non-treated diesel exhaust?

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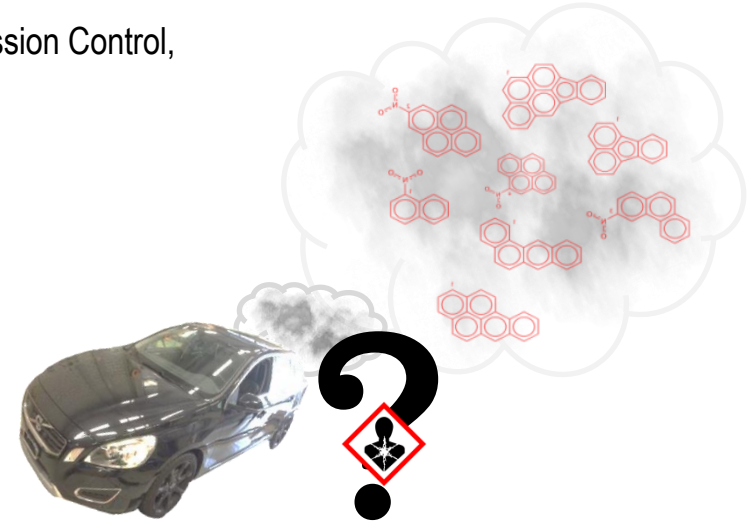
Advanced Analytical Technologies

Empa, Dübendorf



Motivation and objectives

International Agency for Research on Cancer
World Health Organization

Miners study, Silverman et al. JNCI, 104(11), 2011

Gasoline Direct Injection

30% of EU fleet will be GDI in 2020

?

Are GDI vehicle exhaust genotoxic like non-treated diesel exhaust?

Recent press release (May 2017)

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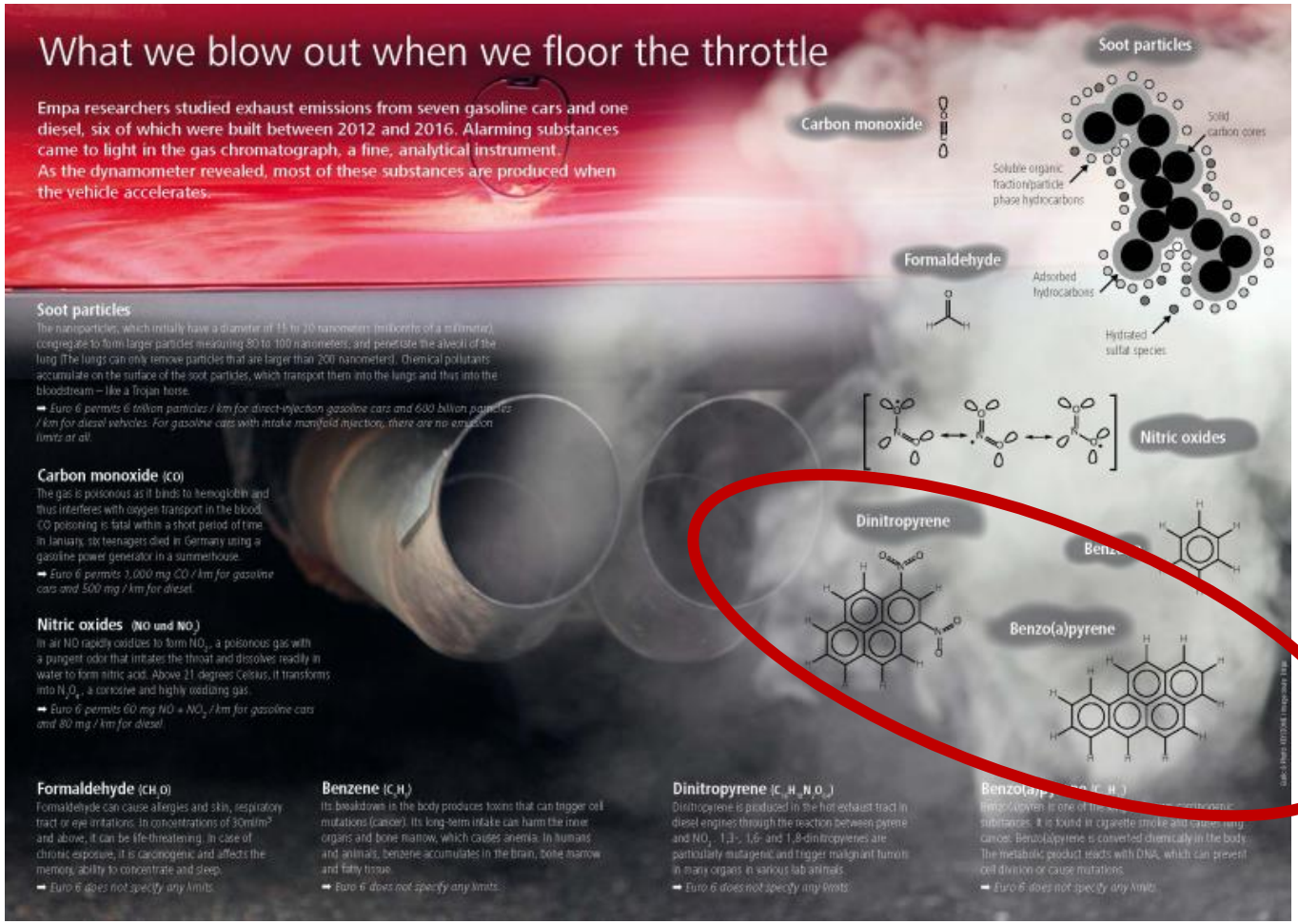
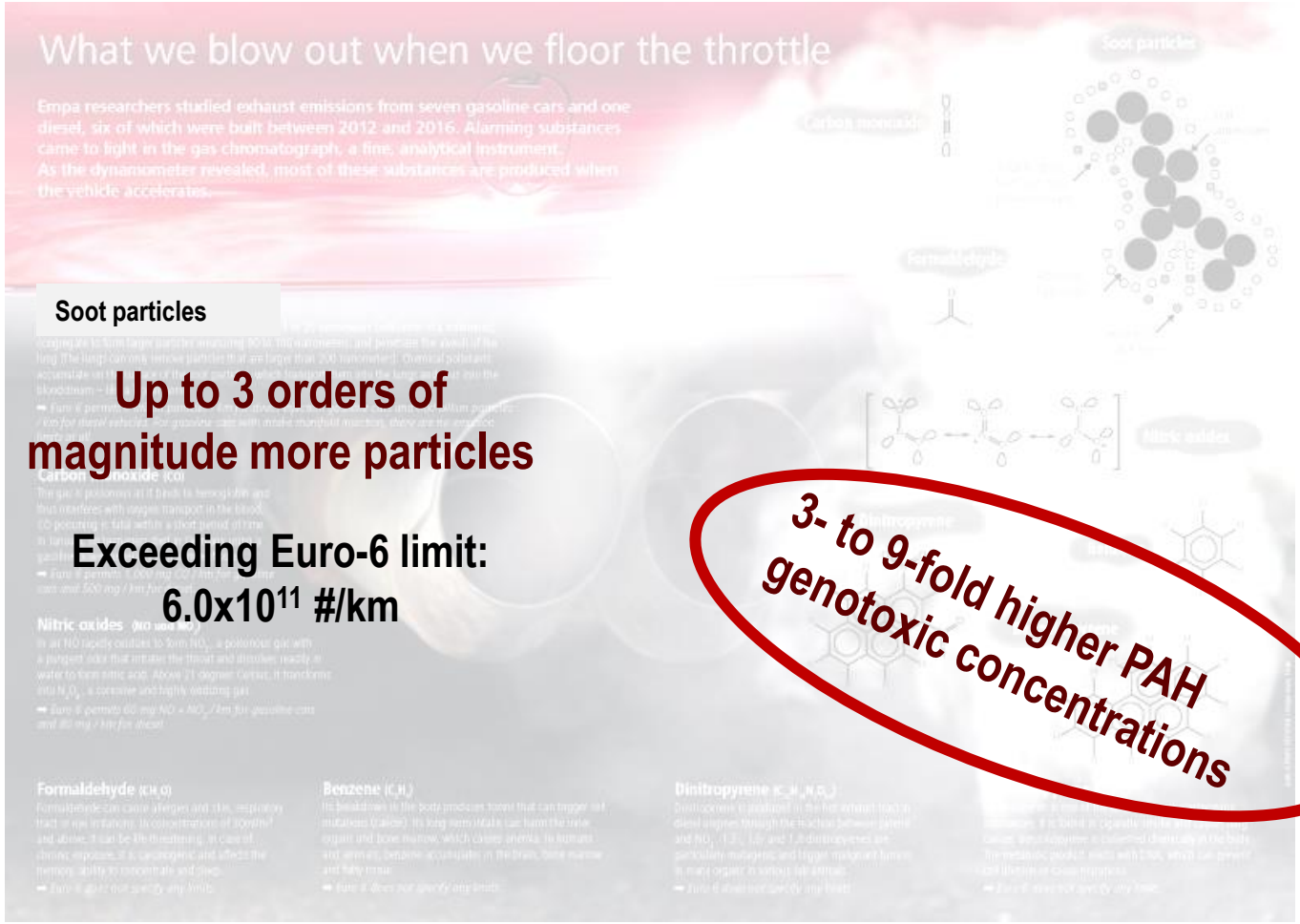


In comparison with diesel….

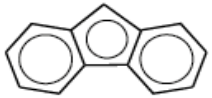


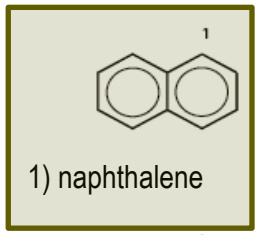
Carcinogenic PAHs

AGENTS CLASSIFIED BY THE *IARC MONOGRAPHS*, VOLUMES 1–111

Group 1	*Carcinogenic to humans*	116 agents
Group 2A	*Probably carcinogenic to humans*	70
Group 2B	*Possibly carcinogenic to humans*	285
Group 3	*Not classifiable as to its carcinogenicity to humans*	506
Group 4	*Probably not carcinogenic to humans*	1

International Agency for Research on Cancer
World Health Organization



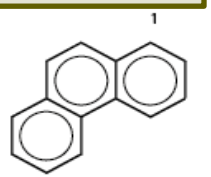


1) naphthalene

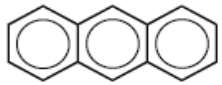
2) acenaphthylene

3) acenaphthene

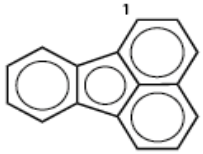
4) fluorene



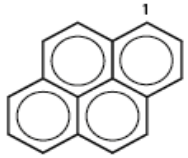
5) phenanthrene



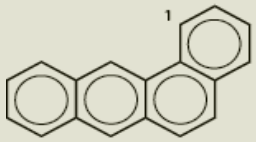
6) anthracene



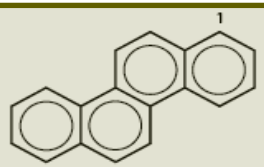
7) fluoranthene



8) pyrene

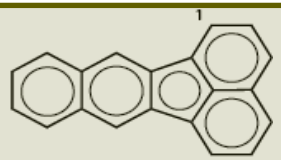


9) benzo(a)anthracene



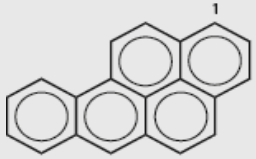
10) chrysene

11) benzo[b]fluoranthene

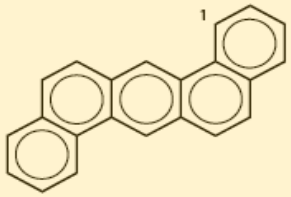


12) benzo[k]fluoranthene

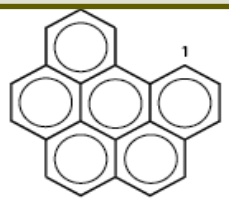
↑ MW
↓ vapor pres.
andsolubility



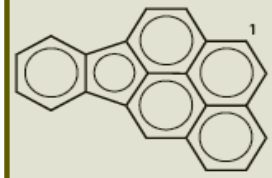
13) benzo[a]pyrene



14) dibenz[ah]anthracene



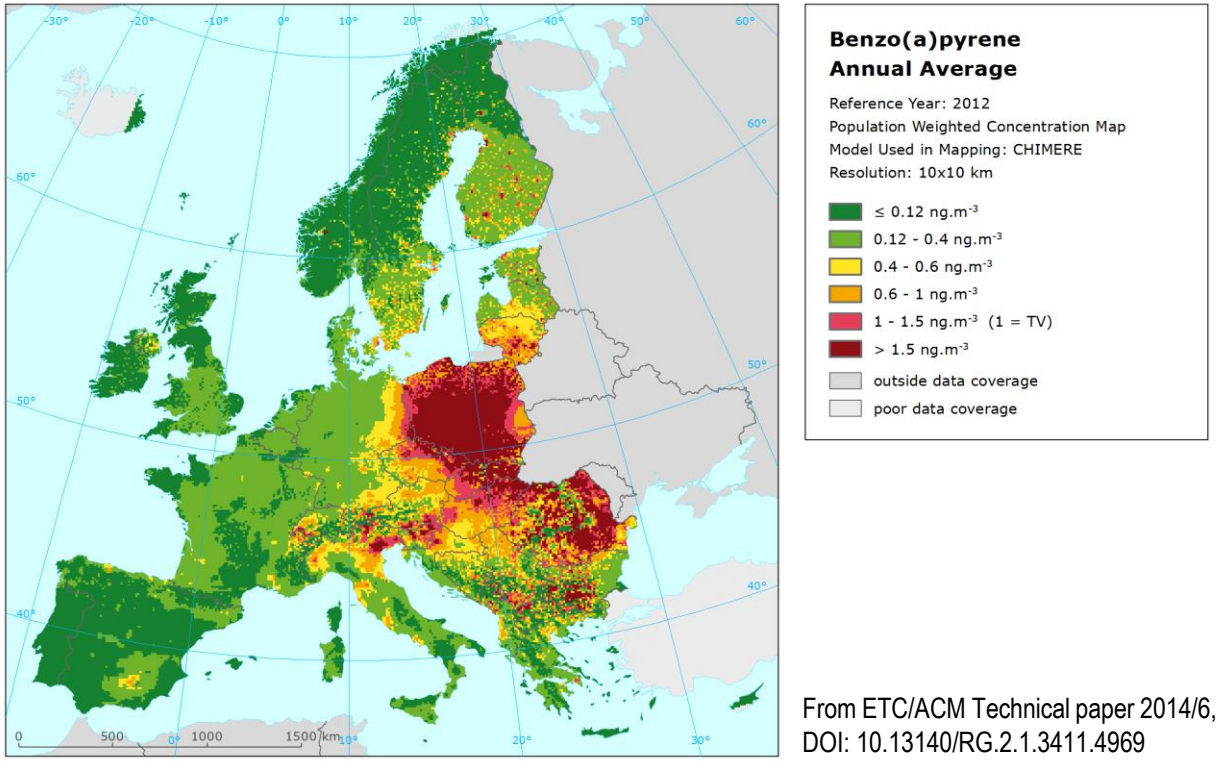
15) benz[ghi]perylene



16) indeno(1,2,cd)pyrene

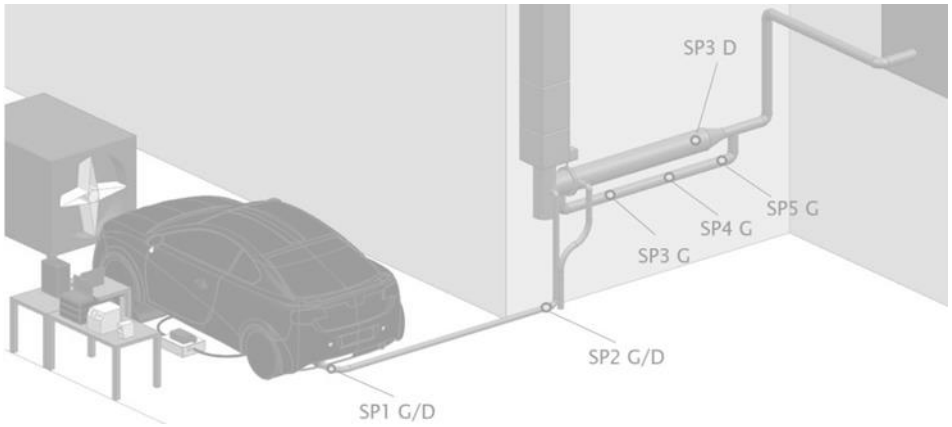
Group 1 **Group 2A** **Group 2B**

- BaP is a marker for total exposure to carcinogenic PAHs
- Air Quality in Europe – 2016 Report (EEA):
  - In 2014, 1/3 of the BaP measurement stations in Europe exceed the target value (1ng/m^3, annual average , 2014/107/EC Directive)
  - Only 12% of the population are exposed to the estimated reference level of 0.12 ng/m^3 (WHO)
  - Emissions of BaP in the EU-28 increased by 1% (2000-2014)



From ETC/ACM Technical paper 2014/6, 2015
DOI: 10.13140/RG.2.1.3411.4969

EXPERIMENTAL SETUP



Experimental procedure

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GDI Fleet (n=7)

Euro-3 Euro-4 Euro-5 Euro-6

Diesel bench mark

Euro-5

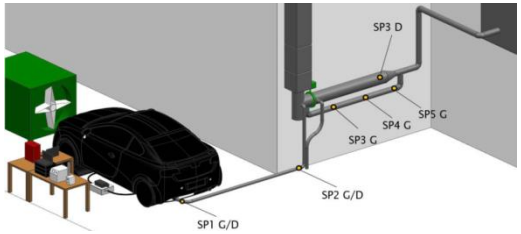
4 particle filters tested

2 coated and 2 non-coated

Biofuels

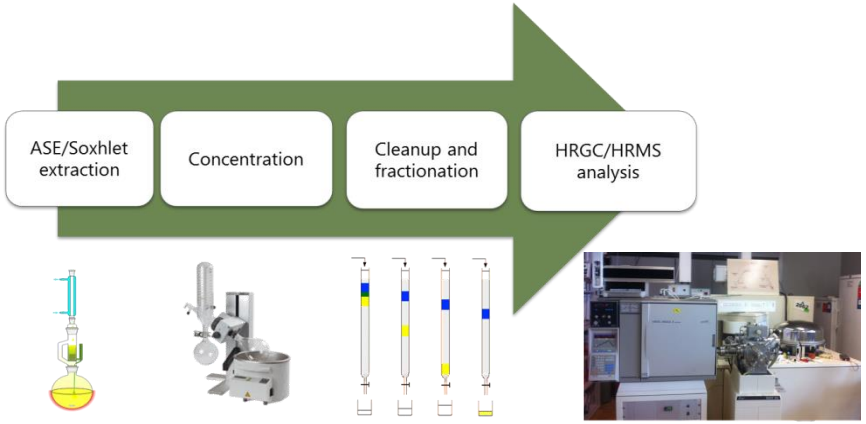
Ethanol and butanol blends

Sampling

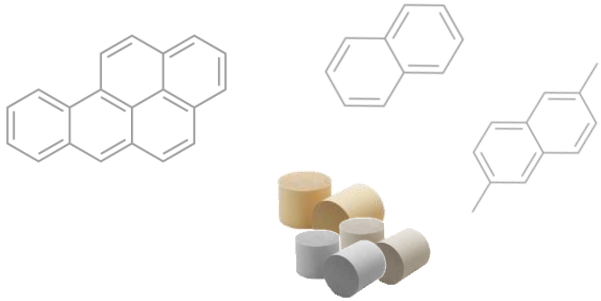


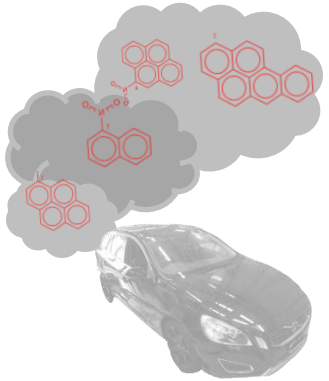
- Chassis dynamometer of the UASB in Nidau
- 2 transient driving cycles (cWLTC and hWLTC) and SSC
- Diluted exhaust --- CVS tunnel: solid + condensed + gaseous phases

Laboratory analysis



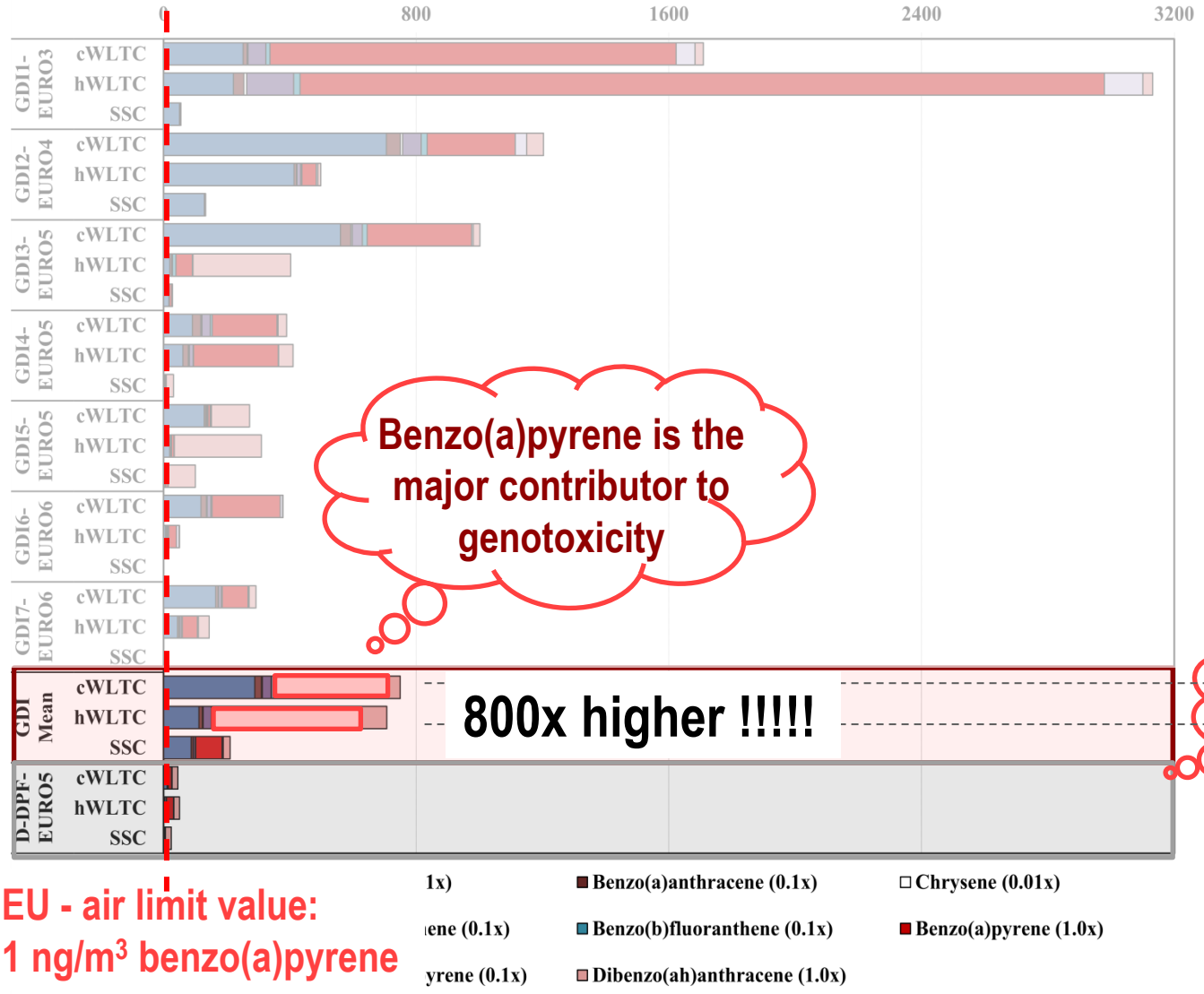
RESULTS





?

On average,



GDI fleet emits

16x (cWLTC)
14x (hWLTC)

than the Diesel bench-mark with DPF

EU - air limit value:
1 ng/m^3 benzo(a)pyrene

Solutions are needed to lower emissions…
at least to diesel with DPF levels

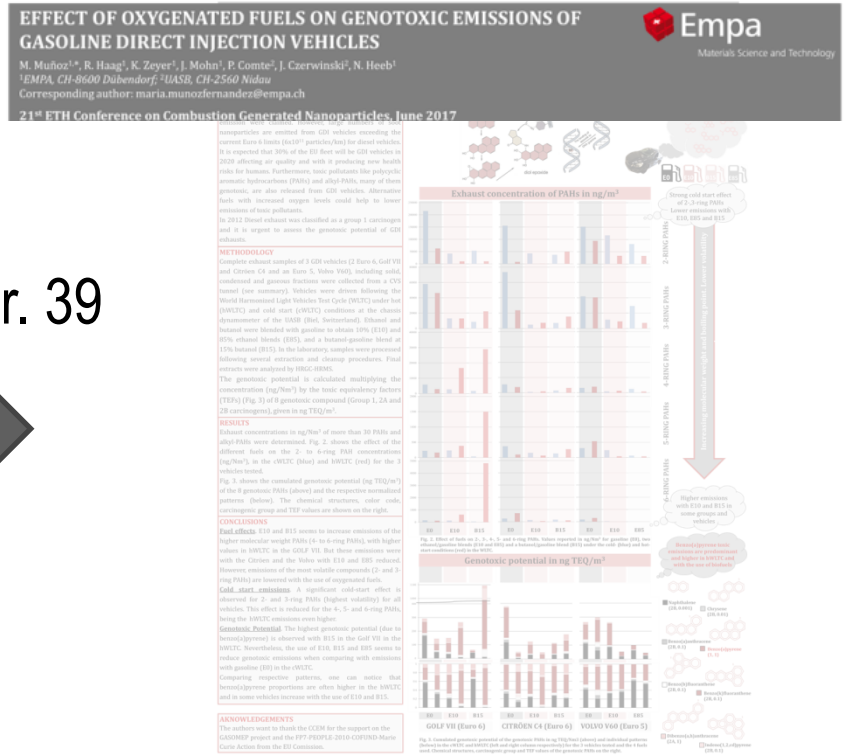
Aftertreatment:

Filters

Alternative fuels

Oxygenated fuels

Poster Nr. 39



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Solutions are needed to lower emissions…
at least to diesel with DPF levels

Poster Nr. 39

Genotoxic concentration

Euro-5

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FILTERS: 2 coated + 2 non-coated

Storage / Release ?

*I.C. Nisbeth, P.K.L. Toxic equivalency factors (TEFs) for polycyclic aromatic hydrocarbons (PAH). Regul Toxic Pharmacol. 16:290-300; 1992

Genotoxic concentration

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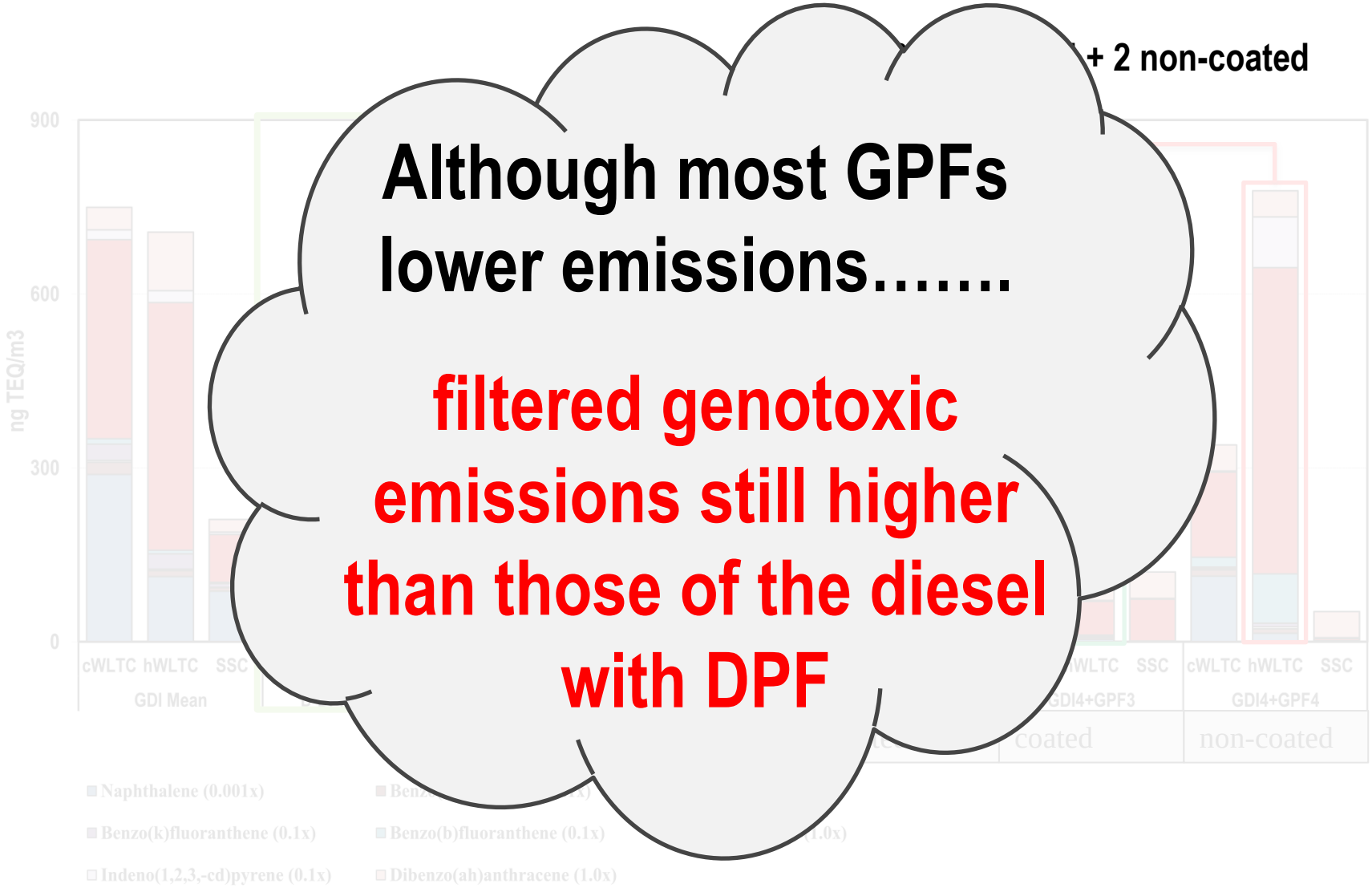

Although most GPFs lower emissions…….

filtered genotoxic emissions still higher than those of the diesel with DPF

*I.C. Nisbeth, P.K.L. Toxic equivalency factors (TEFs) for polycyclic aromatic hydrocarbons (PAH). Regul Toxic Pharmacol. 16:290-300; 1992

The benzo(a)pyrene example (less volatile, carcinogenic)

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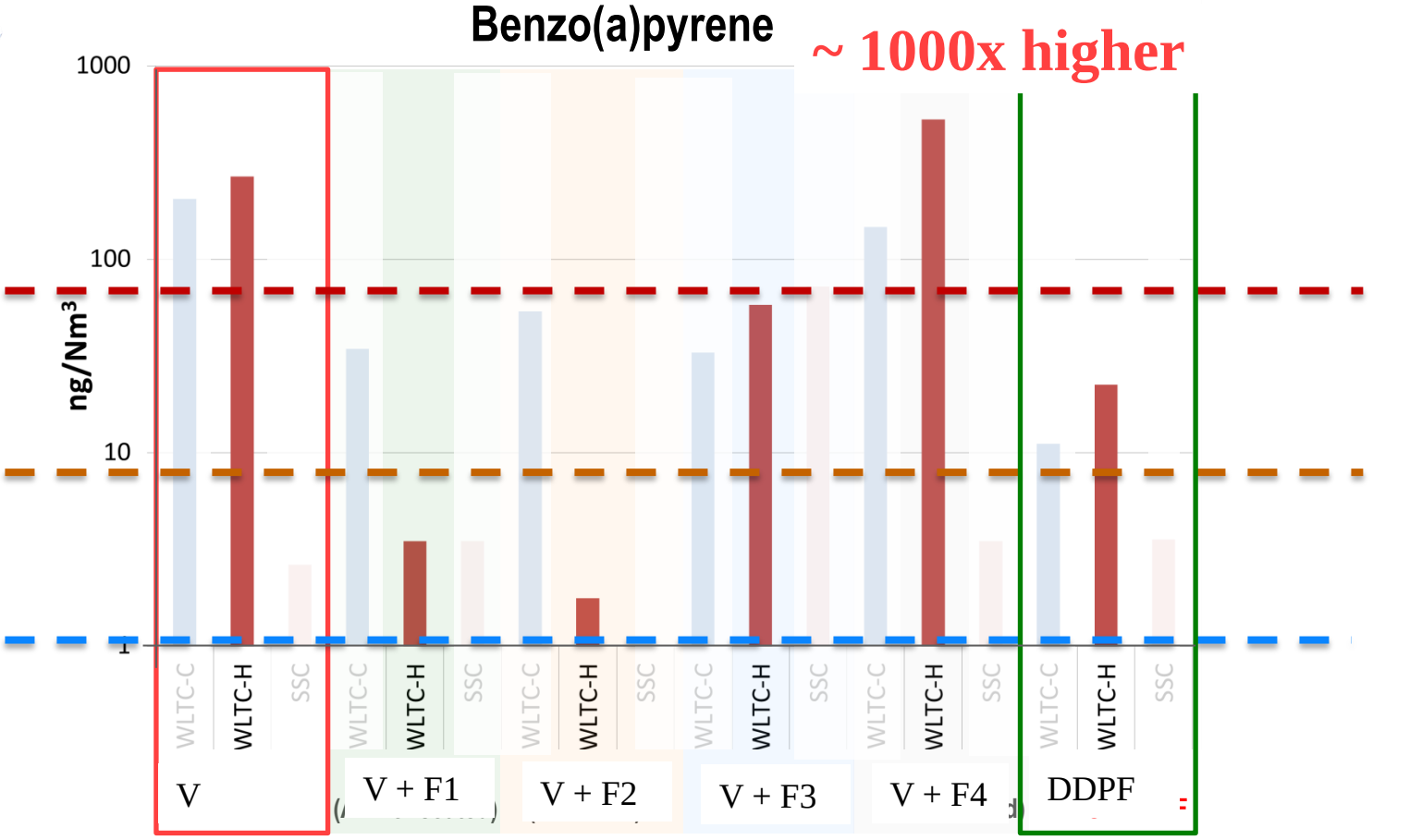
Euro-5 GDI vehicle

Diesel emissions BaP
78-92 ng/Nm^3 without DPF

< 10 ng/Nm^3 with DPF
(Mean values)

Directive 2004/107/EC
BaP target value in ambient air: 1 ng/m^3



CONCLUSIONS / SUGGESTIONS

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- Benzo(a)pyrene concentrations are 1-3 orders of magnitude higher than EU Target Limit (1 ng/m^3)
- Not a big difference between coated and non-coated
- Overall, PAH emissions are lowered with filter (20-80%)
- Filter 4 increases PAH emissions (x2)
- Toxic equivalent concentrations are several times higher in GDI (with and without fitler) than in diesel with DPF.

Are GDI vehicle exhaust genotoxic like non-treated diesel exhaust?

- GDI should be equipped with filters
- GPF should undergo certification procedures like DPF (VERT)
- New or used filters
- Analysis of PCDD/Fs

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Thank you for your attention

Questions?