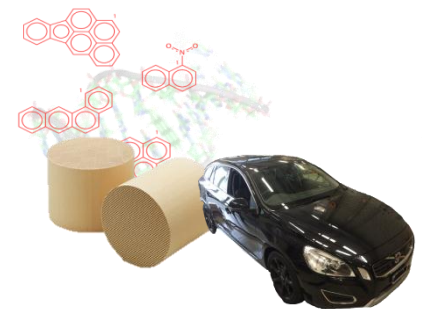


# Assessment of the genotoxic potential of GDI-vehicles with different GPFs

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Advanced Analytical Technologies, EMPA Dübendorf



## Particles exceed those of diesel with filter

(Mohr et al., Environ. Sci. Technol., 40 2375-2383, 2006)



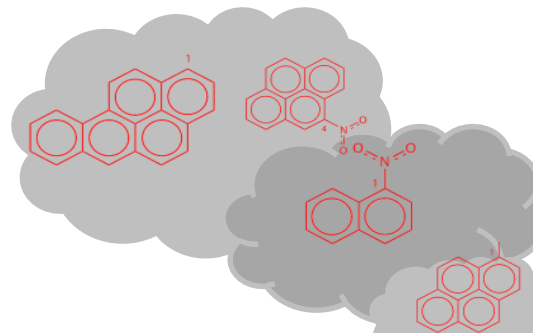
GDI vehicle

**WE HAVE SEEN THAT!!!!!!**

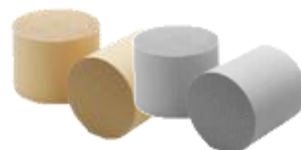
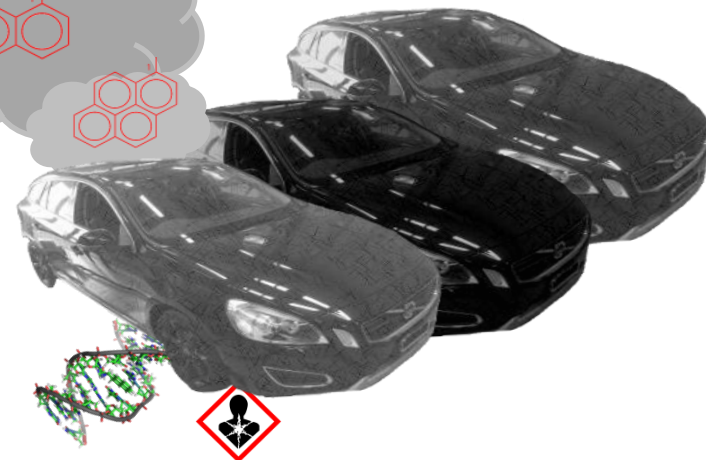
**1000x** more than other gasoline vehicles

**10x** more than new diesel vehicles

Exceeding EU limit for Diesel ( $6 \times 10^{11}$ )



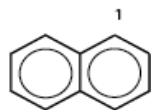
**GENOTOXIC EMISSIONS ?**



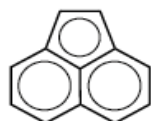
**FILTERS??**



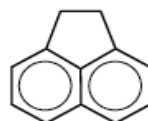
# Polycyclic Aromatic Hydrocarbons



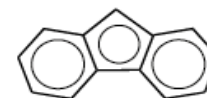
1) naphthalene



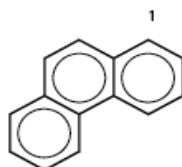
2) acenaphthylene



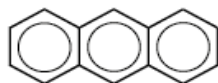
3) acenaphthene



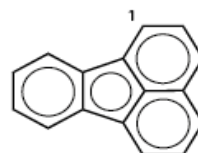
4) fluorene



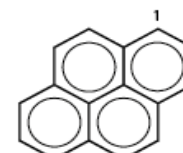
5) phenanthrene



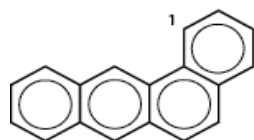
6) anthracene



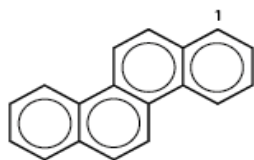
7) fluoranthene



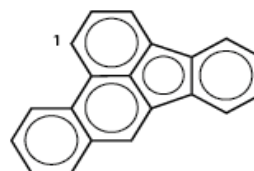
8) pyrene



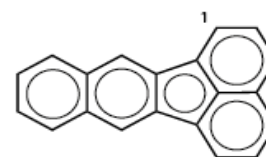
9) benzo(a)anthracene



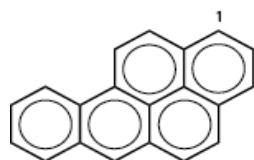
10) chrysene



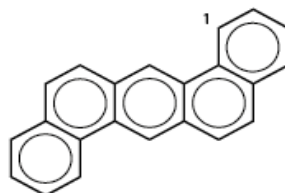
11) benzo[b]fluoranthene



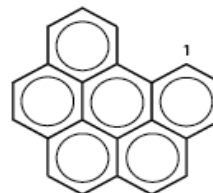
12) benzo[k]fluoranthene



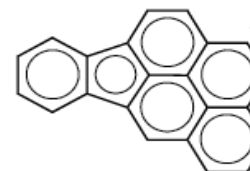
13) benzo[a]pyrene



14) dibenz[ah]anthracene



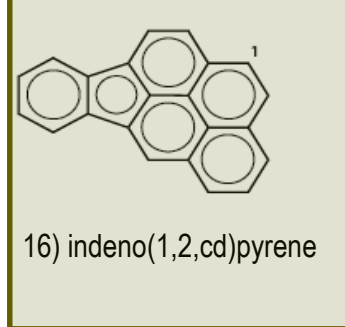
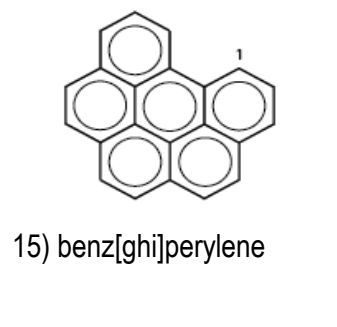
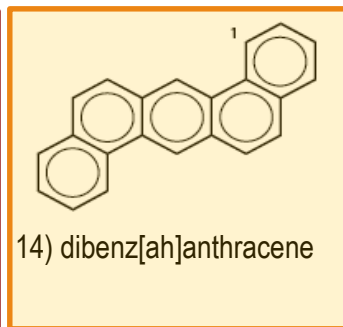
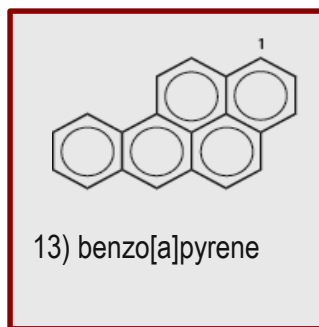
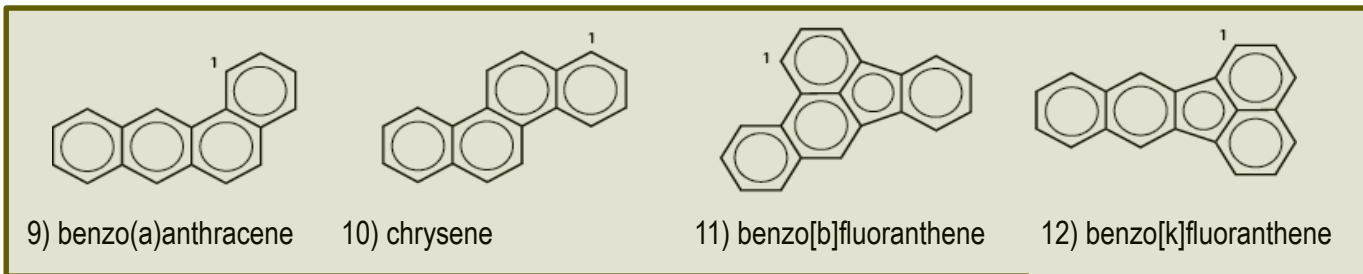
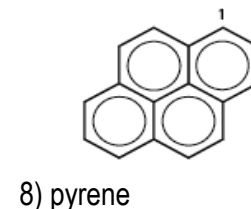
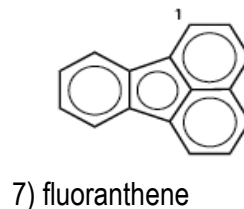
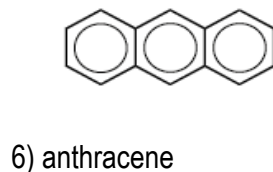
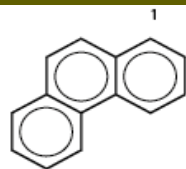
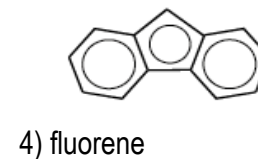
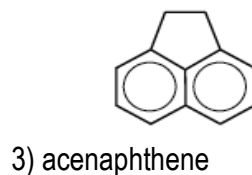
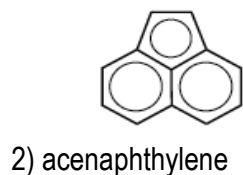
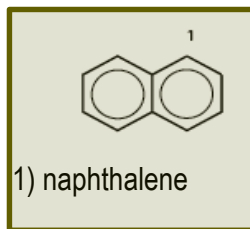
15) benz[ghi]perylene



16) indeno(1,2,cd)pyrene



# Carcinogenicity



**Group 1**

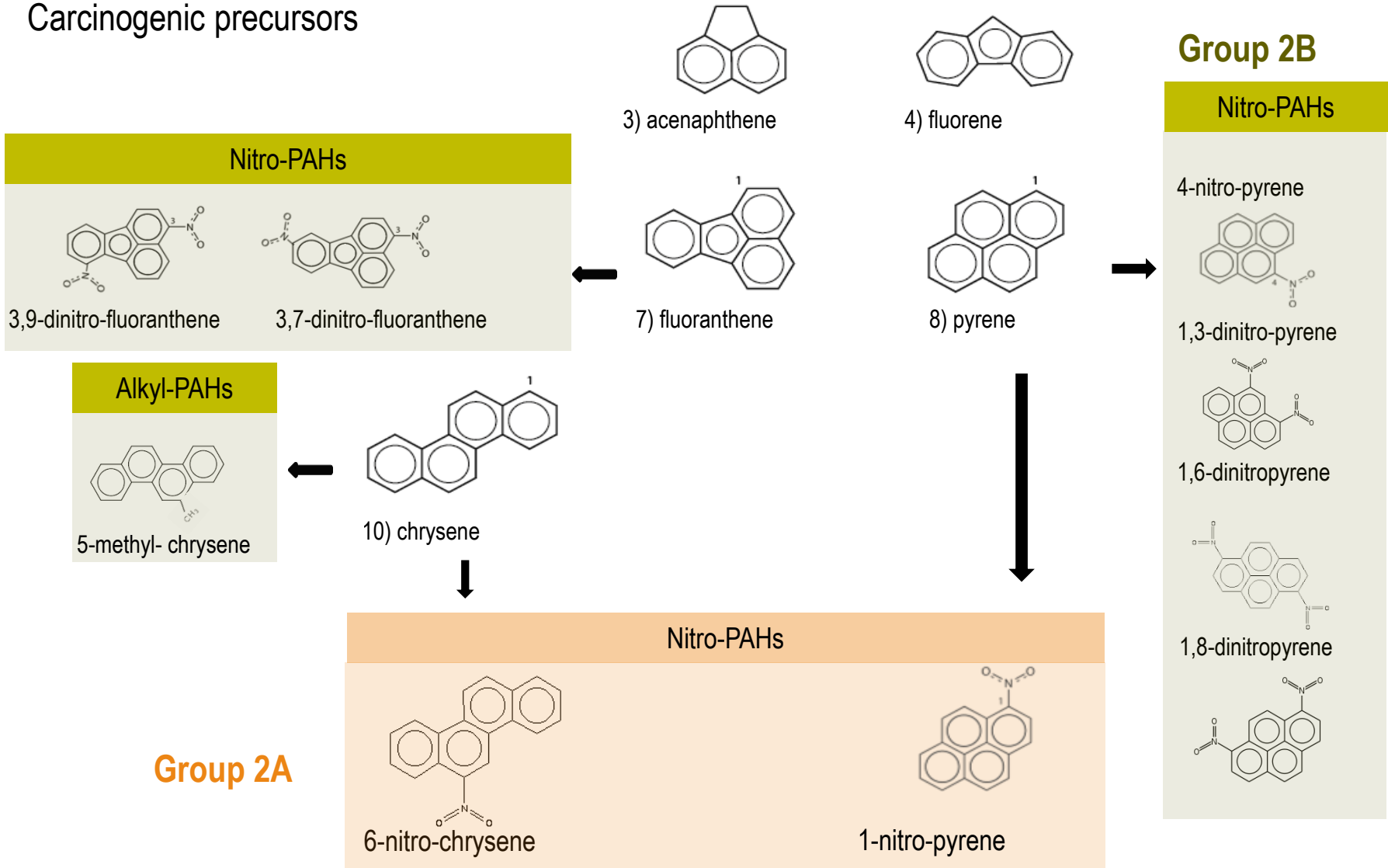
**Group 2A**

**Group 2B**



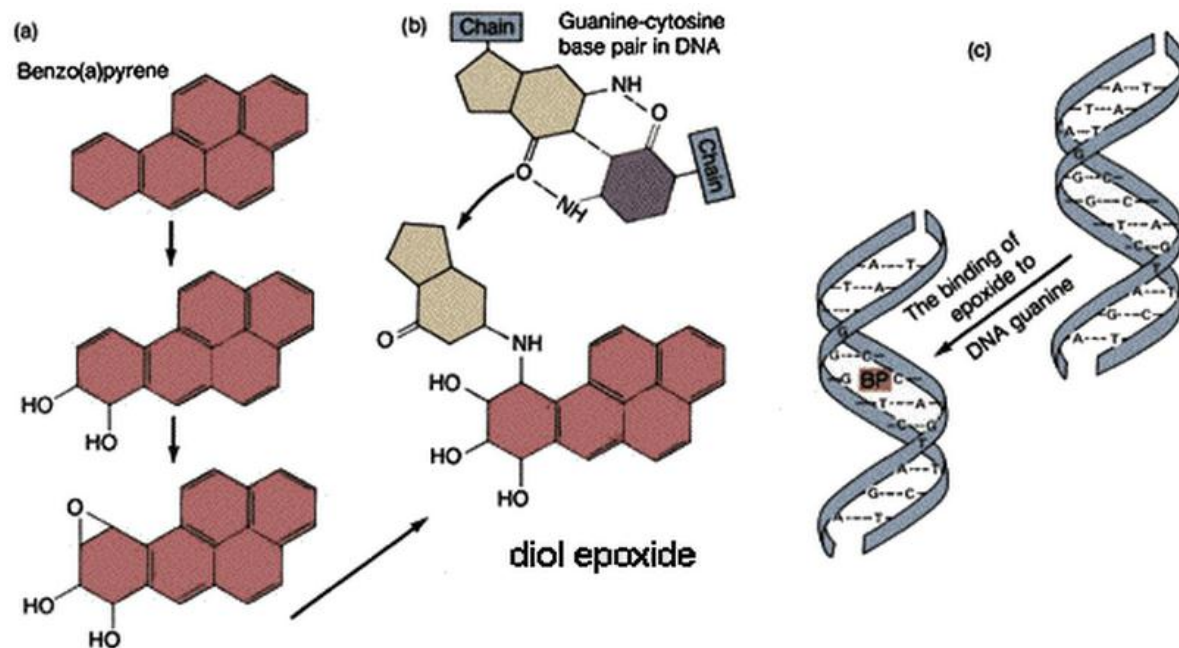
# nitroPAHs

## Carcinogenic precursors



# Genotoxicity

In genetics, genotoxicity describes the property of some chemical agents that damages the genetic information within cells causing mutations which may lead to cancer.



# Experimental procedure

- Volvo V60 T4F 1.6 L, Euro 5
- Opel Zafira with F1
- 4 filters (2 brands)

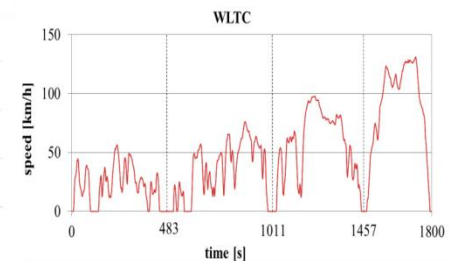
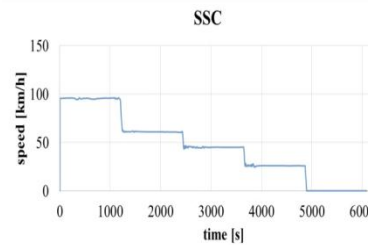


Filter 1	A - Non-coated
Filter 2	A - Coated
Filter 3	B - Coated
Filter 4	B - Non-coated

- Chassis dynamometer of the UASB in Nidau

- Driving cycles :

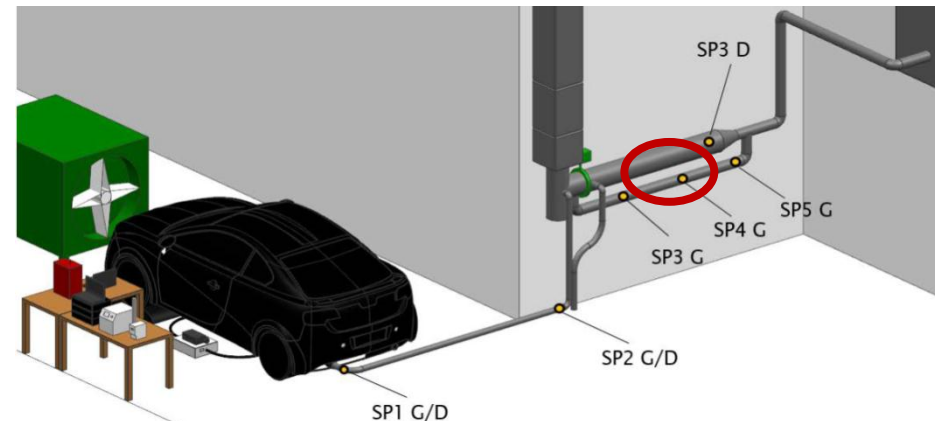
- WLTC (transient, cold and hot)
- SSC, stationary



- Diluted exhaust --- CVS tunnel:
- solid + condensed + gaseous phases

## Laboratory analysis

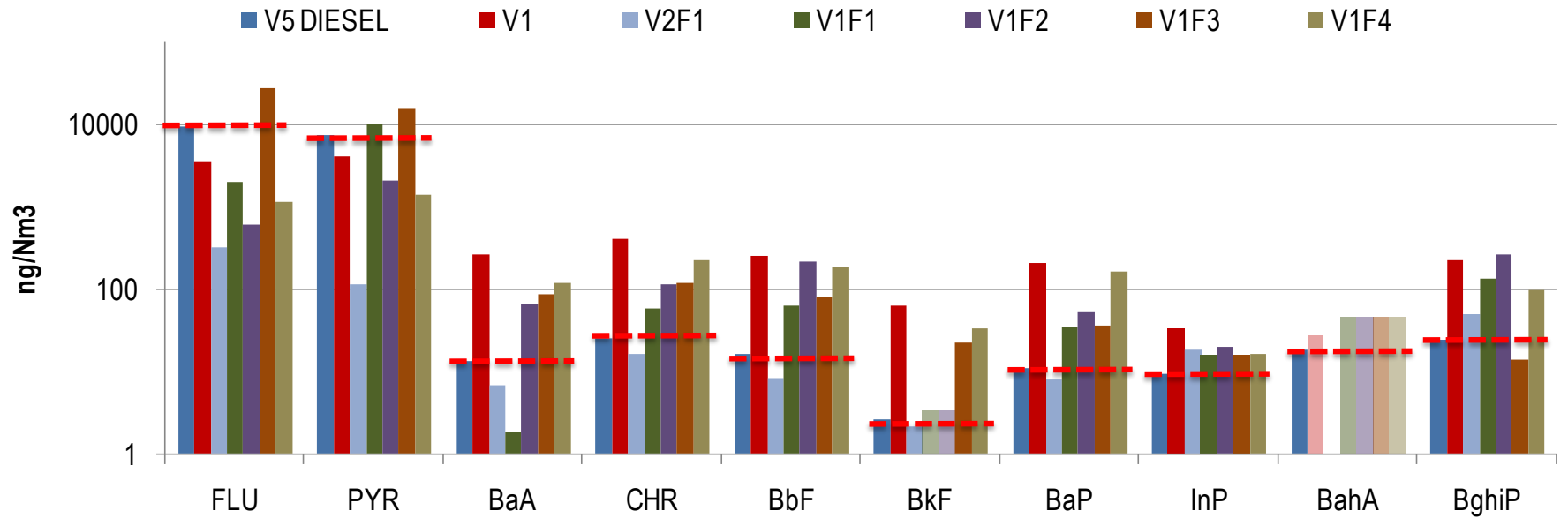
- Multi-step clean-up procedure
- HRGC-HRMS



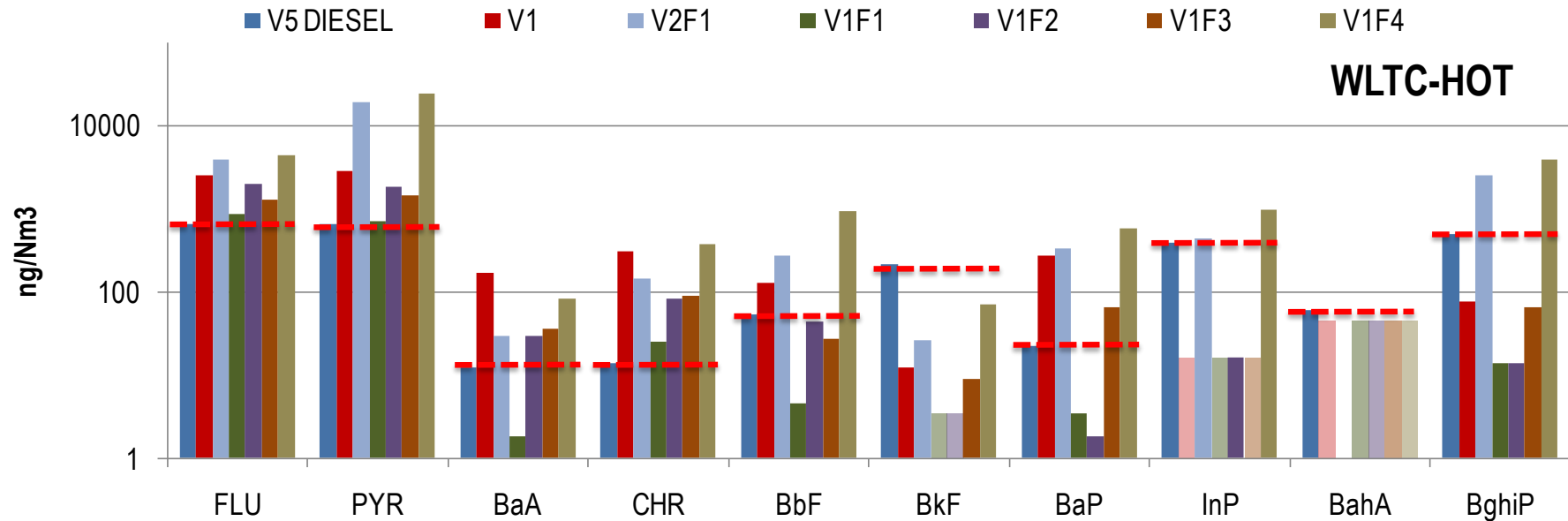
# **PAH emissions FILTERS in GDI and DIESEL**

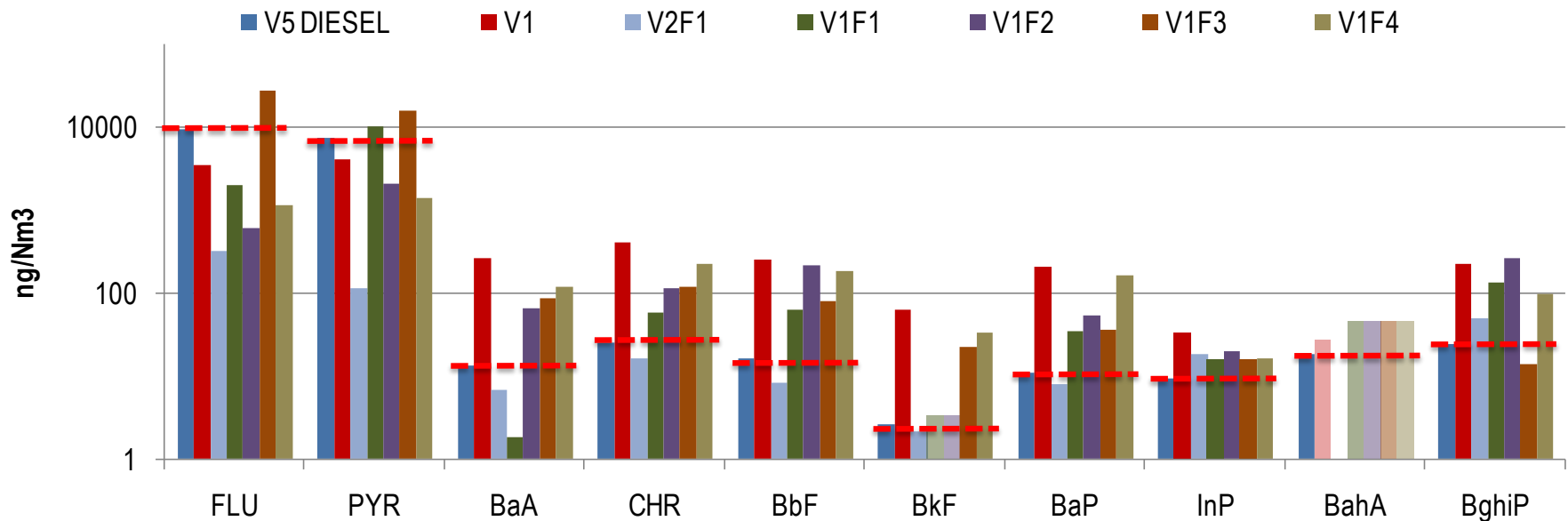


# WLTC-COLD



# WLTC-HOT





**F4 and F3 → higher emissions  
F1 in V2**

**Particle counts filtration efficiencies (PCFE)**

- WLTC cold:
  - ~76 % F3 COATED
  - ~74 % F4 UNCOATED
- Higher PCFE in SSC and idling



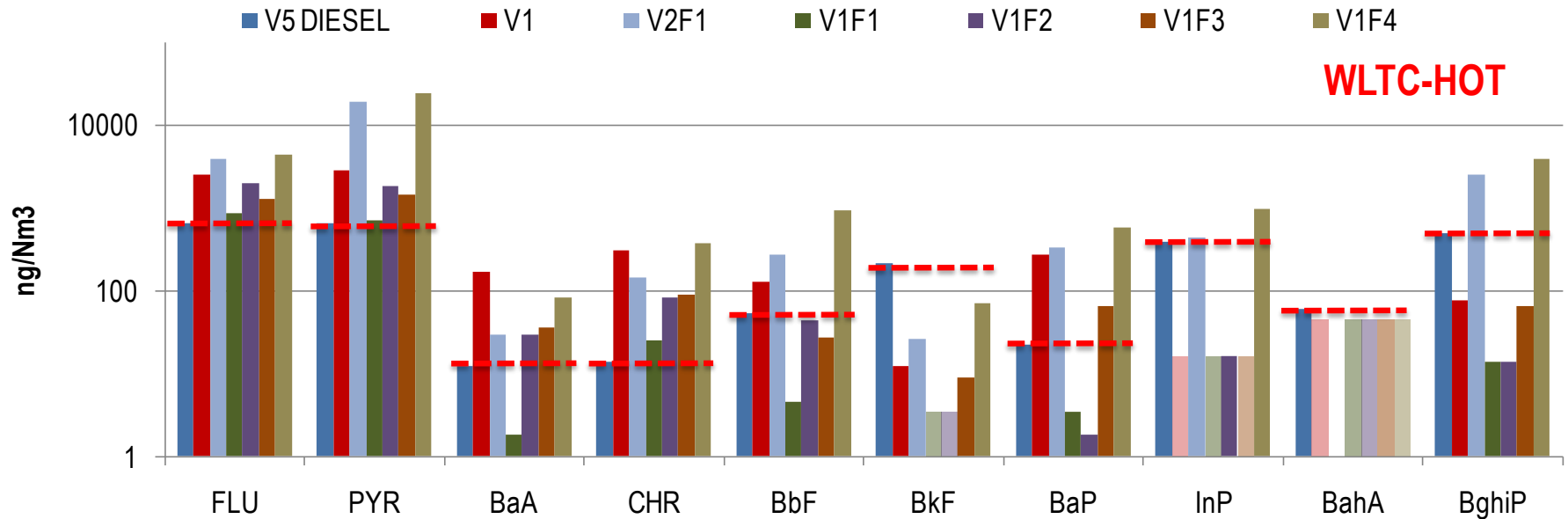
**F4 → higher emissions  
F1 in V2**

### Particle counts filtration efficiencies (PCFE)

- WLTC hot:

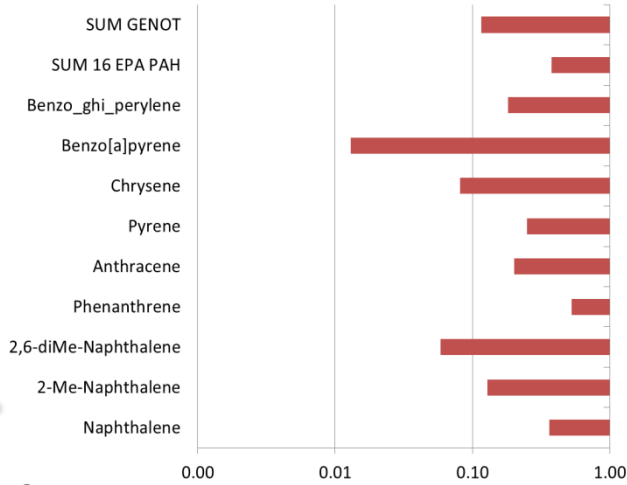
~78 % F3 COATED

~80% F4 UNCOATED

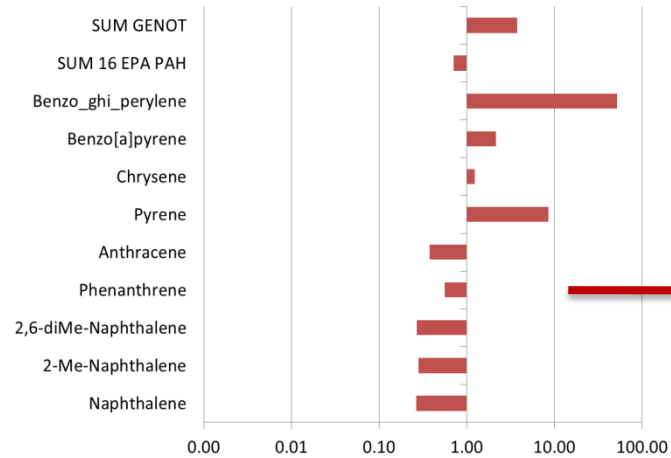


# Efficiencies (ratio hot/hot)

### F1 UNCOATED

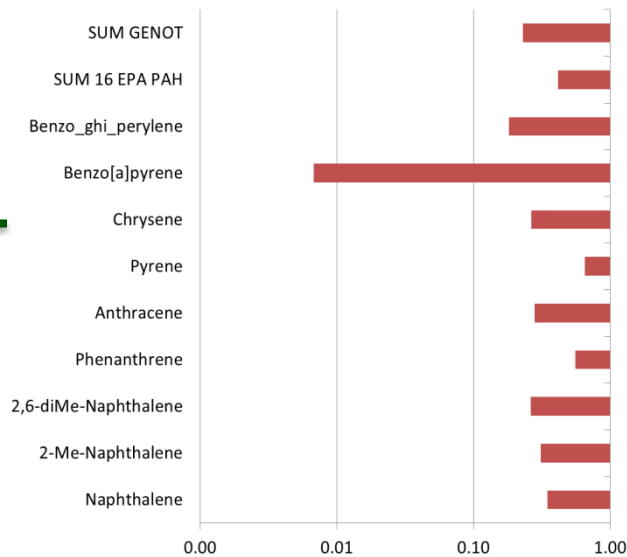


### F4 UNCOATED

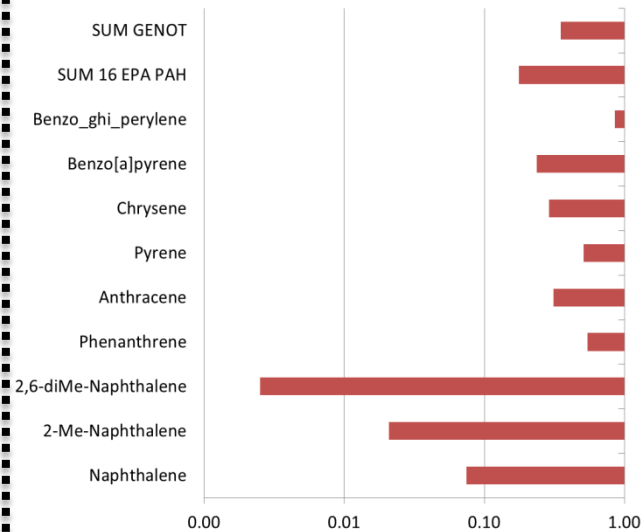


Release? →

### F2 COATED



### F3 COATED

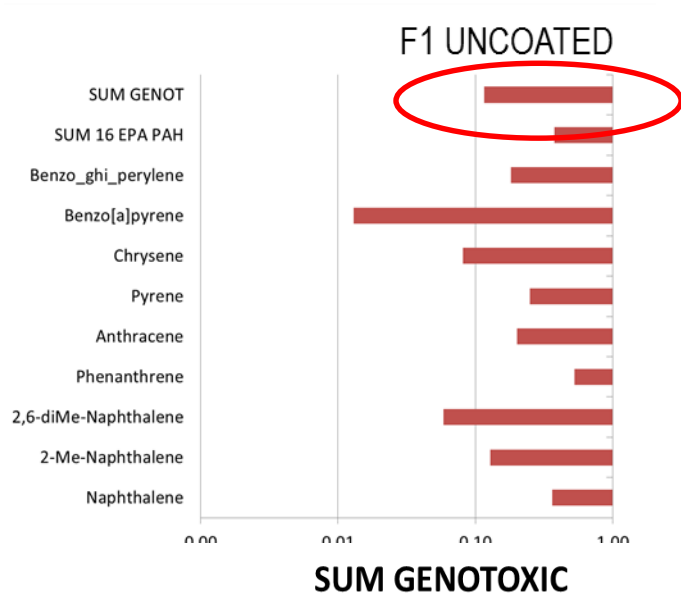


← Storage?

←

←



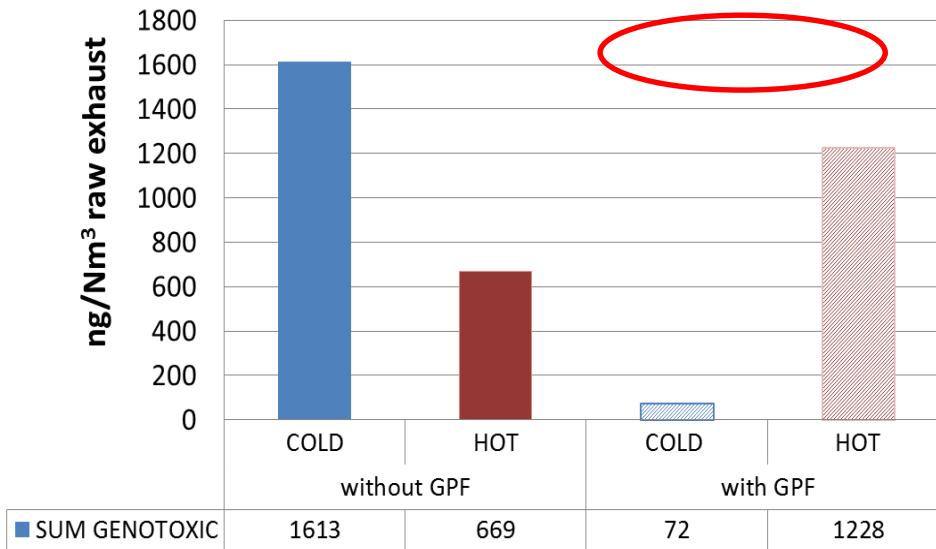


### PAH reductions (sum of 7 genotoxic PAHs)

- WLTC hot:
  - ~88 % F1 UNCOATED
  - ~77 % F2 COATED

### Particle counts filtration efficiencies (PCFE)

- WLTC hot:
  - ~98 % F1 UNCOATED
  - ~90 % F2 COATED



Filter 1 used with vehicle 2 showed an increase of 100% in the genotoxic PAHs

**x2 increase**



# PAHs

## PAH reductions (sum of 7 genotoxic PAHs)

- WLTC hot:

~65 % F3 COATED

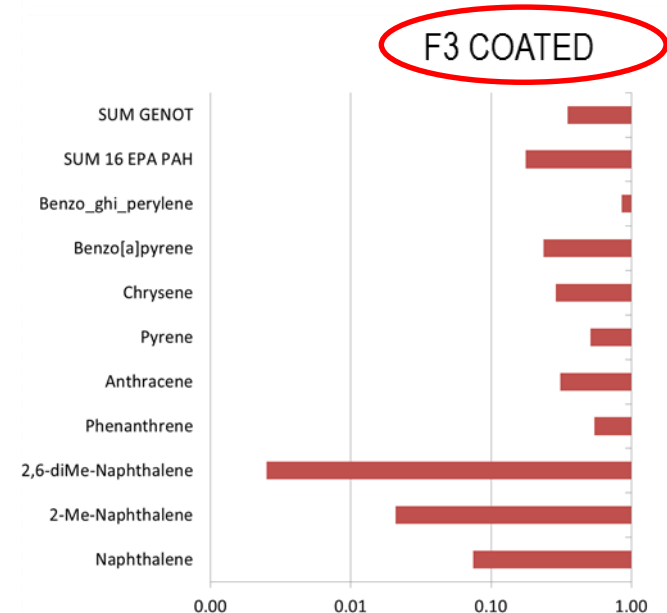
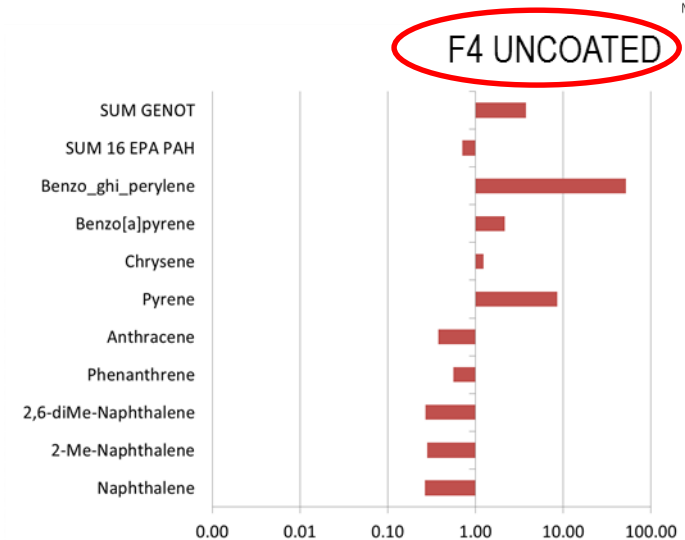
~ x4 INCREASE F4 COATED

## Particle counts filtration efficiencies (PCFE)

- WLTC hot:

~76 % F3 COATED

~75 % F4 UNCOATED



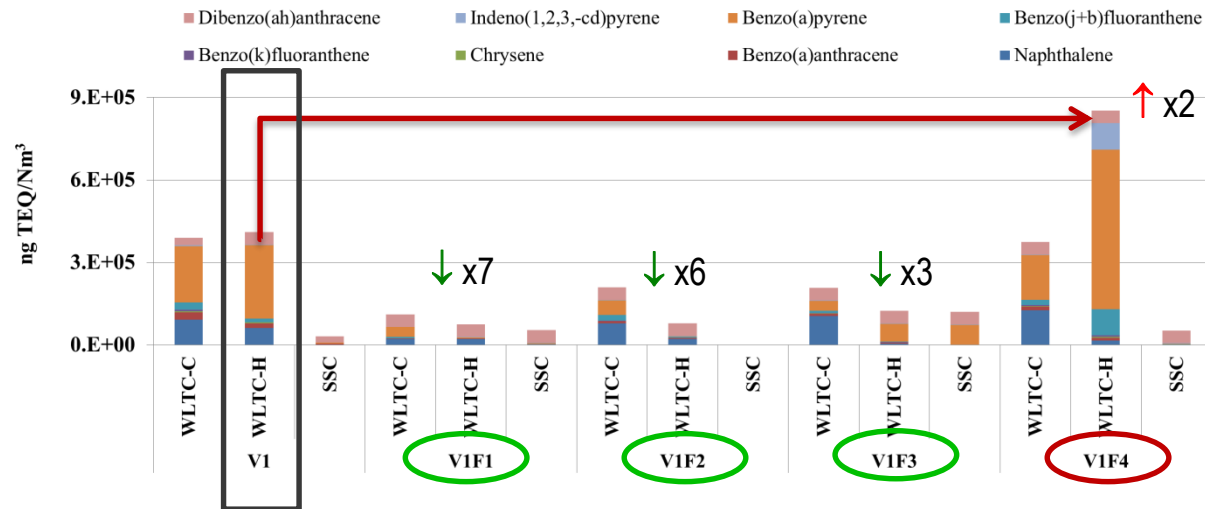
# Toxic equivalent concentration

## Toxic equivalency factors

Compound	TEFs
Chrysene	0.01
Benzo(k)fluoranthene	0.1
Benzo(b)fluoranthene	0.1
Benzo(a)pyrene	1
Indeno(1,2,3,-cd)pyrene	0.1
Dibenzo(ah)anthracene *	1
Benzo(ghi)perylene	0.01

TEF x C (ng/Nm<sup>3</sup>)

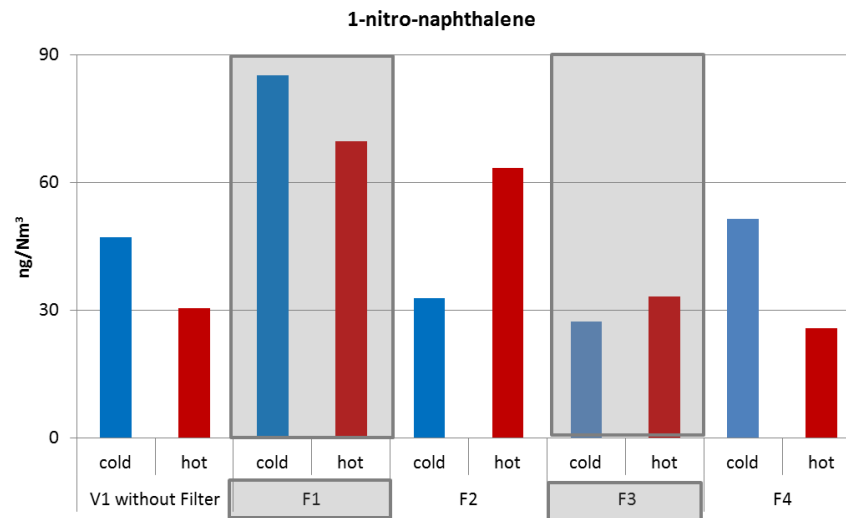
Filter 1	A - Non-coated
Filter 2	A - Coated
Filter 3	B - Coated
Filter 4	B - Non-coated



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



Filter 1-4 with vehicle 1 (reference)



## Ambient air levels:

1-nitro-naphthalene: 0.39-5.71 ng/m<sup>3</sup>

Health Criteria 229, WHO, 2004

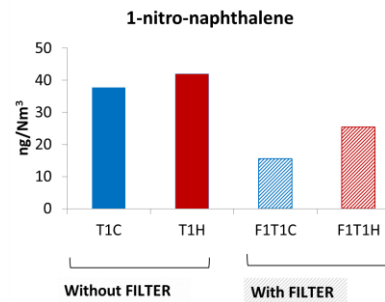


## Diesel levels (raw exhaust):

### 1-nitro-naphthalene

NO FILTERED: 170 - 560 ng/m<sup>3</sup>

FILTERED: 4 - 12 ng/m<sup>3</sup>



Filter 1 with vehicle 2



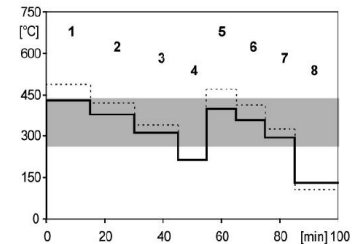
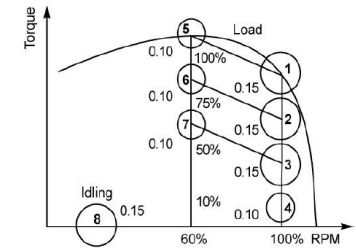


# Comparison HDV vs LDV

## FILTER TESTS:

### HDVs – DIESEL vehicles

- Hot start → 8-stage ISO 8178/4 CI test cycle --- **STATIONARY**
- Liebherr, type 914 T, 6.11 L, 4 cylinders
- New filters → DPFs
- Measurement of regulated pollutants (CO, THC, NO, NO<sub>x</sub>, PN...)
- Non-regulated pollutants (PAHs and PCDD/Fs)



### LDV – Gasoline Direct Injection vehicles

- Hot and cold start → 4-stages WLTC → **TRANSIENT**
- Volvo V60 T4F 1.6 L, Euro 5 → reference
- semi-new filters
- Measurement of regulated pollutants (CO, THC, NO, NO<sub>x</sub>, PN...)
- Non-regulated pollutants (PAHs) → **What about PCDD/Fs?**

