EMPA

Materials Science & Technology

PAH and Nitro-PAH emissions of GDI-vehicles with/without FILTER

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6th VERT FORUM: Particle Filter Technologies

EMPA Dübendorf, March 20th, 2015

International Agency for Research on Cancer

World Health Organization

DIESEL ENGINE EXHAUST

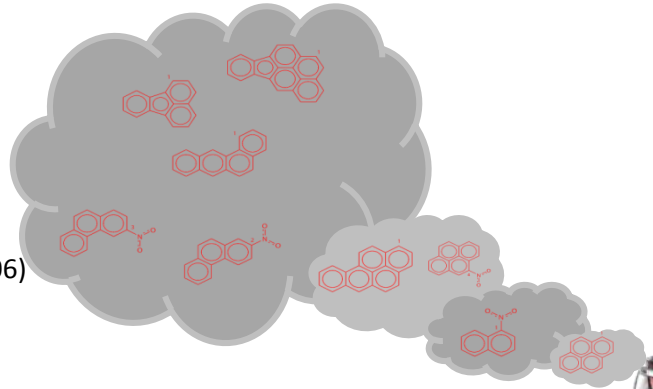
Carcinogenic to humans (Group 1)

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

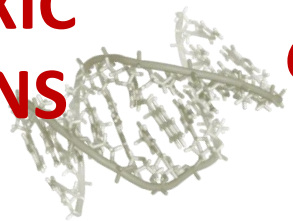
GDI vehicle

Particles exceed those of diesel with filter

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



GENOTOXIC EMISSIONS



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OVERVIEV

INTRODUCTION

- PAHs
- Genotoxicity

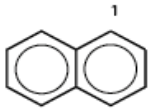
EXPERIMENTS

RESULTS

CONCLUSIONS

PAHs

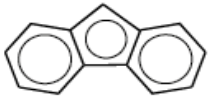
Polycyclic Aromatic Hydrocarbons



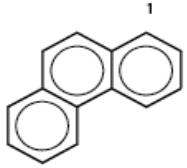
1) naphthalene

2) acenaphthylene

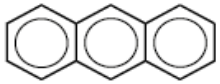
3) acenaphthene



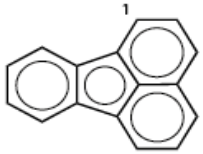
4) fluorene



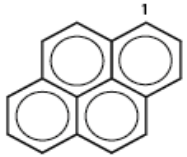
5) phenanthrene



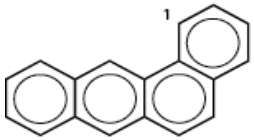
6) anthracene



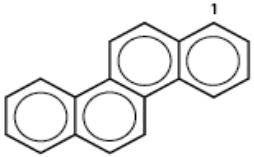
7) fluoranthene



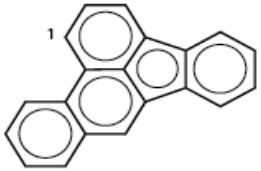
8) pyrene



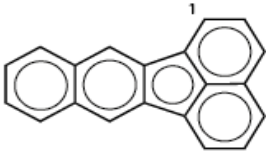
9) benzo(a)anthracene



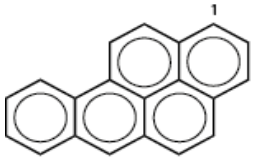
10) chrysene



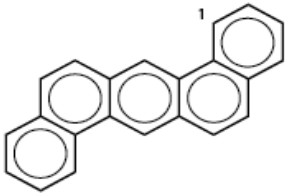
11) benzo[b]fluoranthene



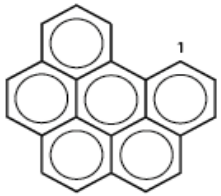
12) benzo[k]fluoranthene



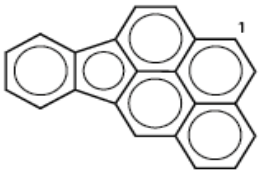
13) benzo[a]pyrene



14) dibenz[ah]anthracene



15) benz[ghi]perylene



16) indeno(1,2,cd)pyrene

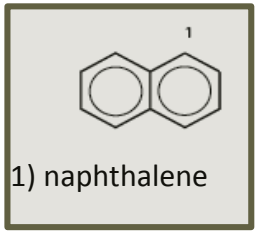
International Agency for Research on Cancer

World Health Organization

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

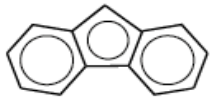
Group 1	*Carcinogenic to humans*	116 agents
Group 2A	*Probably carcinogenic to humans*	70
Group 2B	*Possibly carcinogenic to humans*	285
Group 3	*Not classifiable as to its carcinogenicity to humans*	506
Group 4	*Probably not carcinogenic to humans*	1

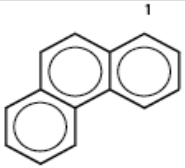
PAHs (Polycyclic Aromatic Hydrocarbons)

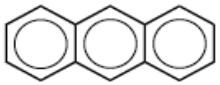

1) naphthalene

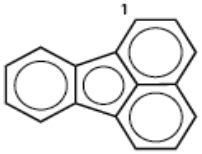

2) acenaphthylene

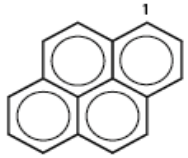

3) acenaphthene

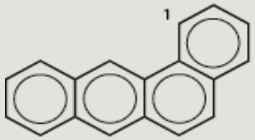

4) fluorene

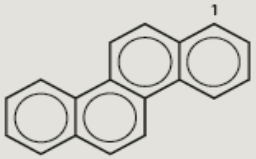

5) phenanthrene

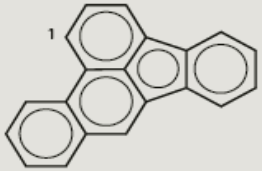

6) anthracene

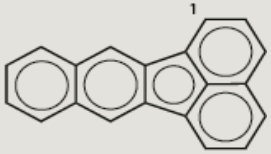

7) fluoranthene

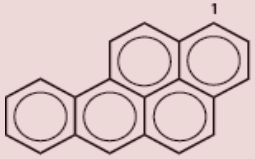

8) pyrene


9) benzo(a)anthracene


10) chrysene


11) benzo[b]fluoranthene


12) benzo[k]fluoranthene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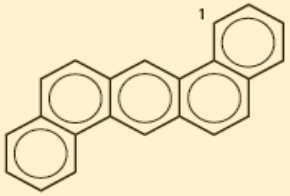
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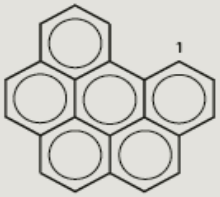
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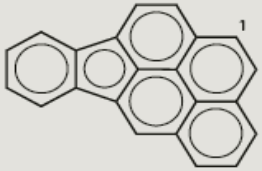
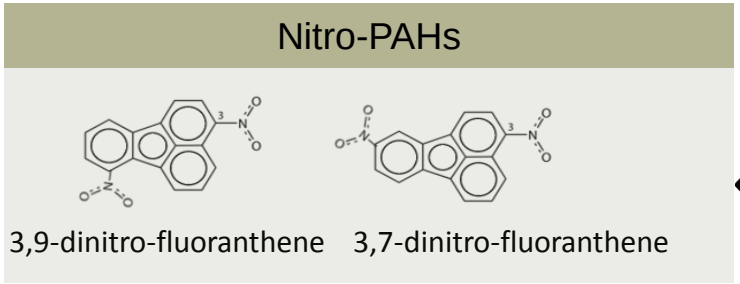

16) indeno(1,2,cd)pyrene

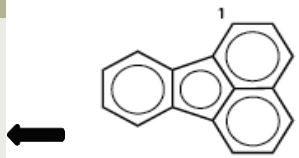
Group 1 **Group 2A** **Group 2B**

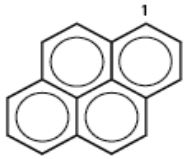
Carcinogen precursors

Group 2B

Nitro-PAHs

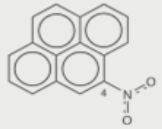


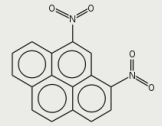

7) fluoranthene


8) pyrene

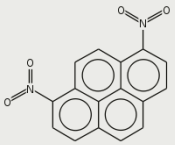
Nitro-PAHs

4-nitro-pyrene

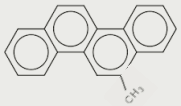

1,3-dinitro-pyrene

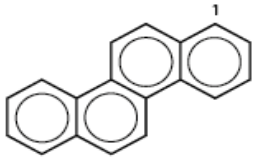

1,6-dinitropyrene


1,8-dinitropyrene



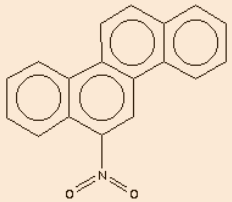
Alkyl-PAHs

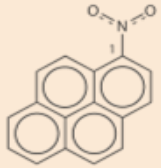

5-methyl- chrysene


10) chrysene

Group 2A

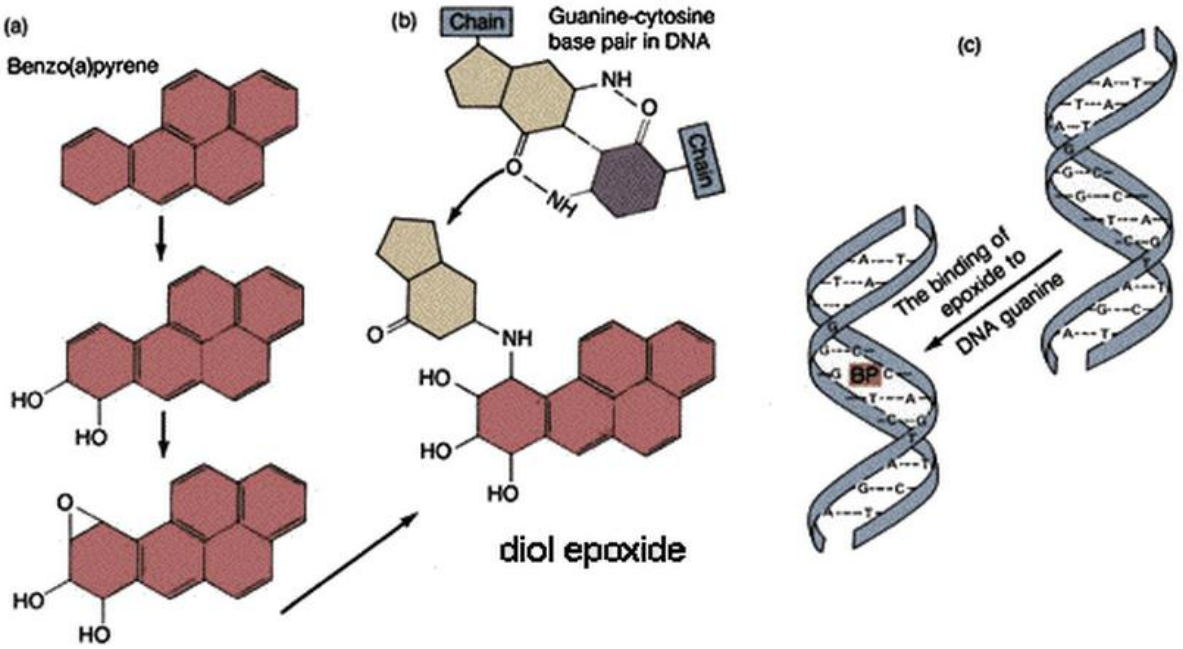
Nitro-PAHs


6-nitro-chrysene


1-nitro-pyrene

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.



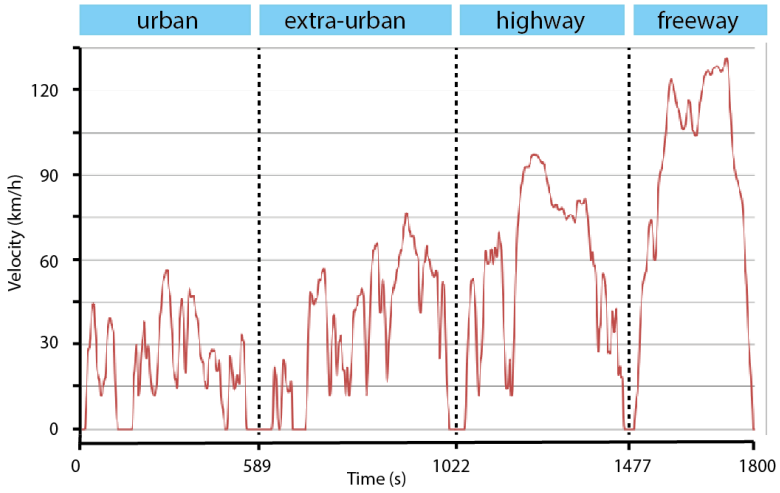
EXPERIMENTAL SETUP

OPEL Insignia 1,6 l (Euro-5)

Chassis dynamometer of the UASB in Nidau

WLTC → **HOT start**

WLTC → **COLD start**



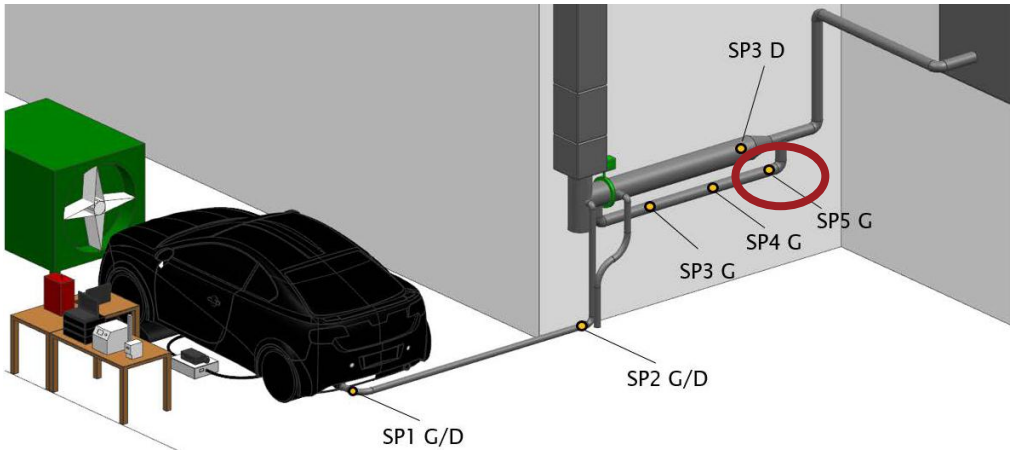
Diluted exhaust --- CVS tunnel:

solid + condensed + gaseous phases

Laboratory analysis

Multi-step clean-up procedure

HRGC-HRMS



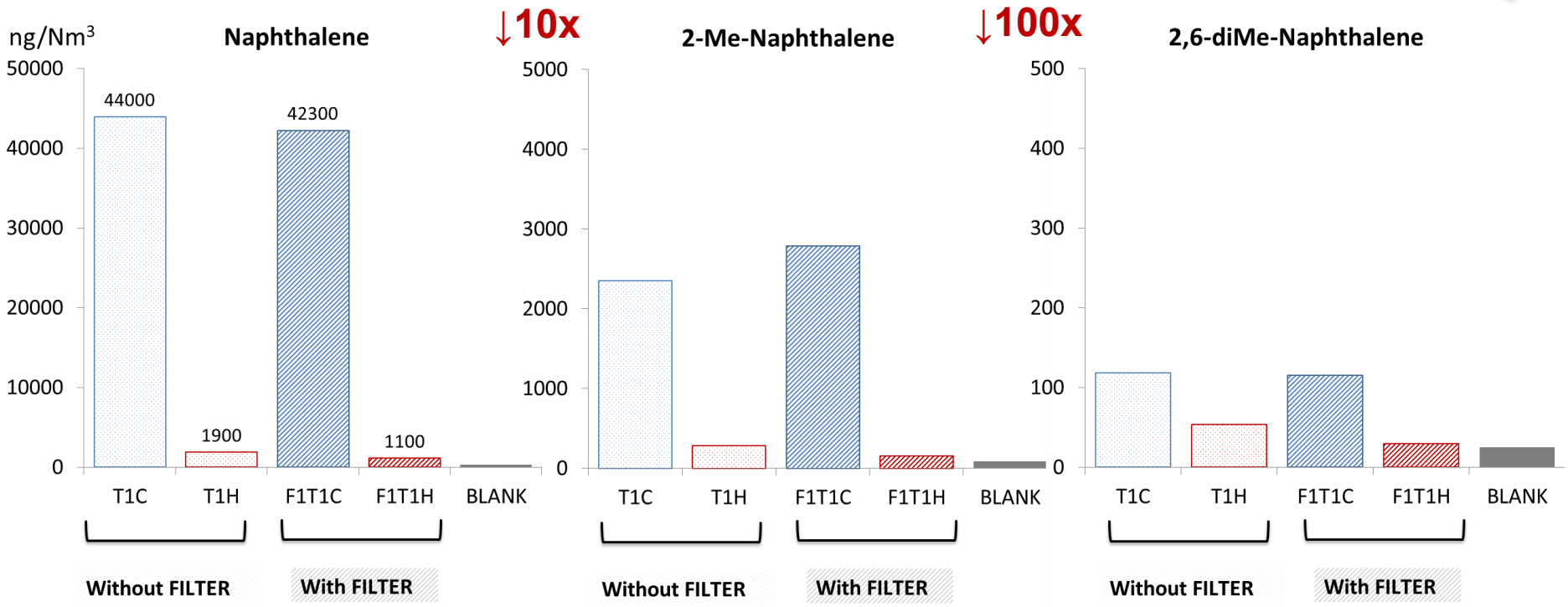
From J. Czerwinski group at Berner Fachhochschule

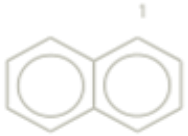
EMPA Materials Science & Technology

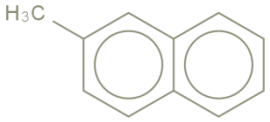
FILTER EFFECT

2-RINGS

Diluted exahust







Huge COLD start effect

No FILTER effect

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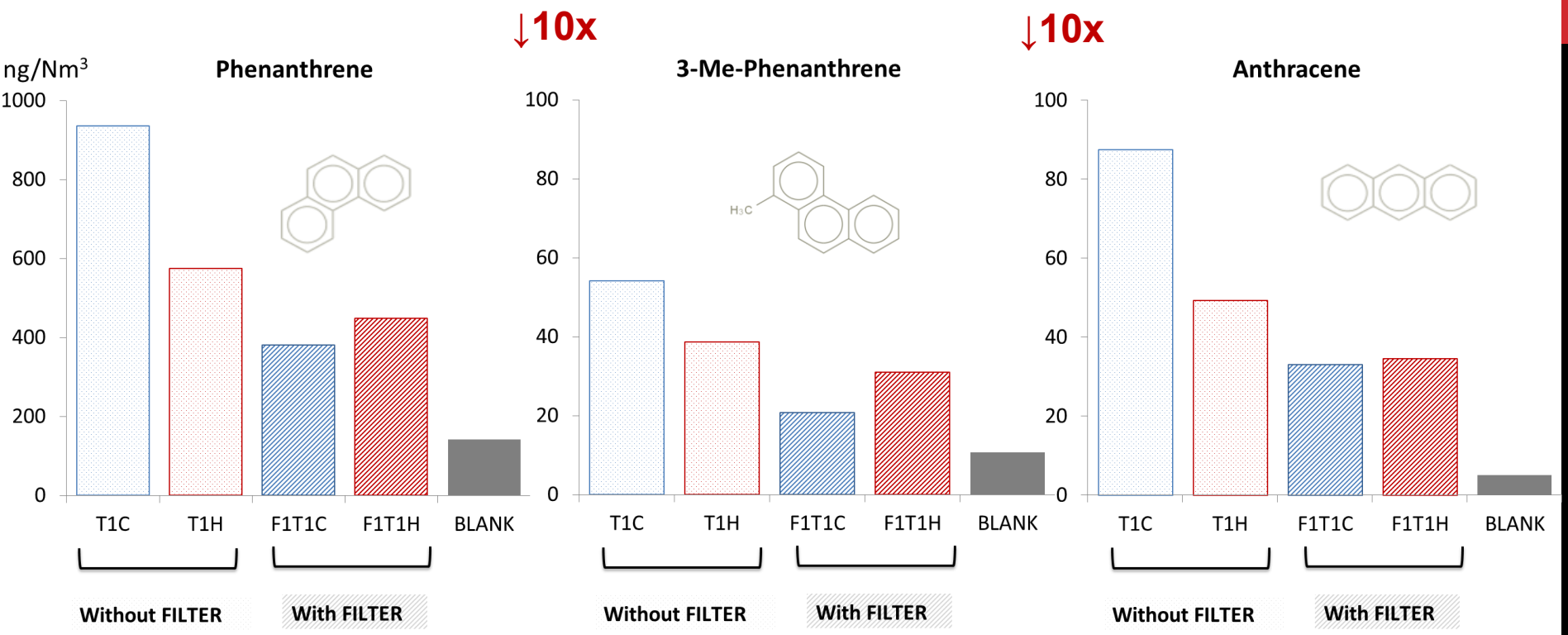
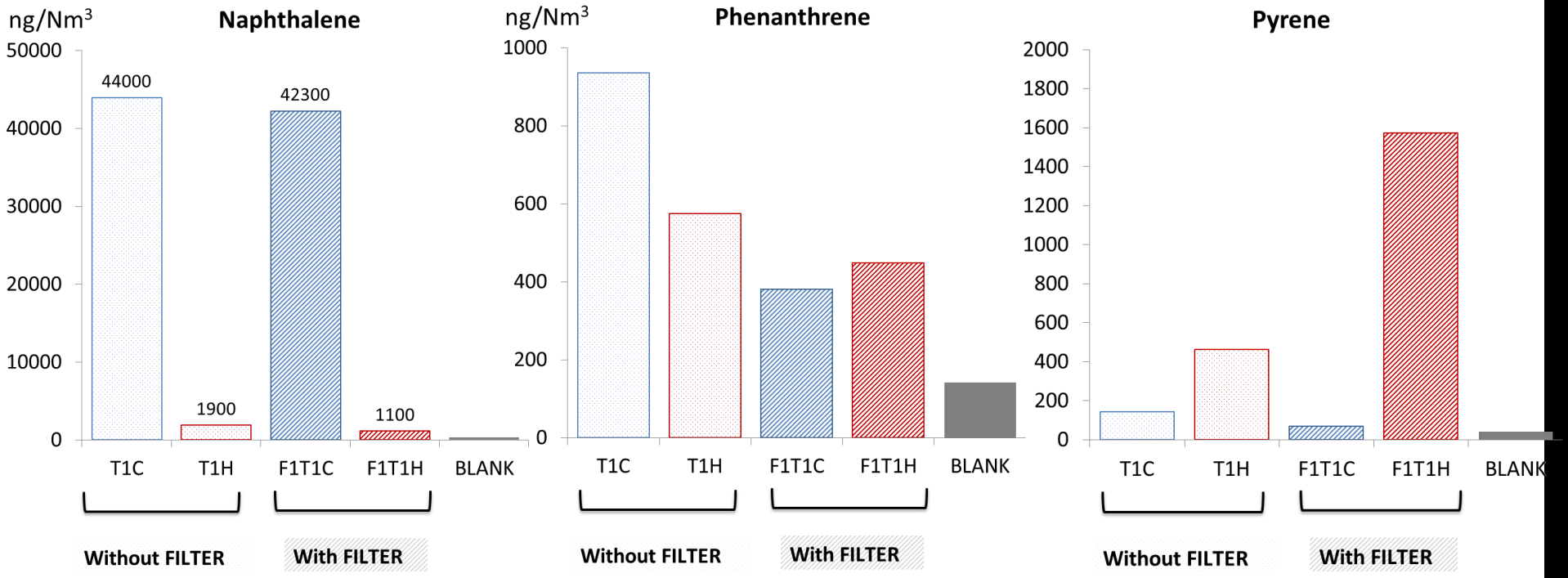
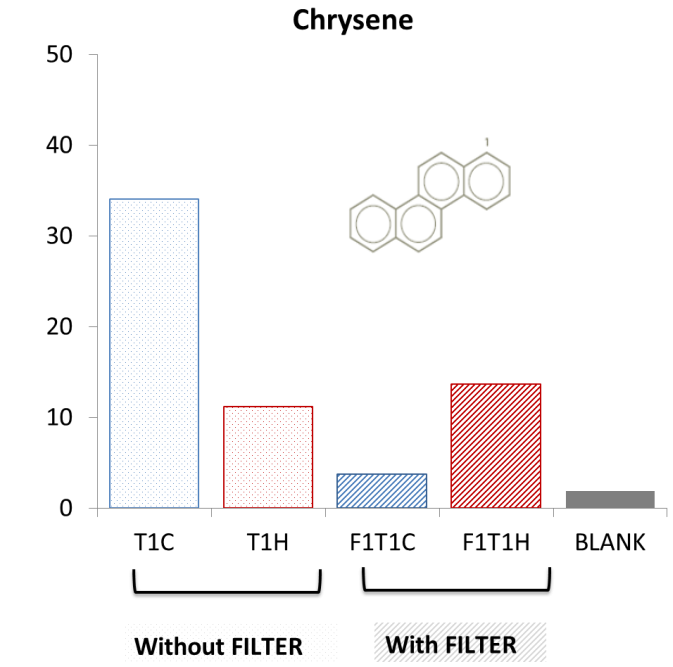
3 RINGS


↓10x
↓10x
ng/Nm3
Phenanthrene
3-Me-Phenanthrene
Anthracene
1000
800
600
400
200
0
100
80
60
40
20
0
H3C
T1C
T1H
F1T1C
F1T1H
BLANK
Without FILTER
With FILTER

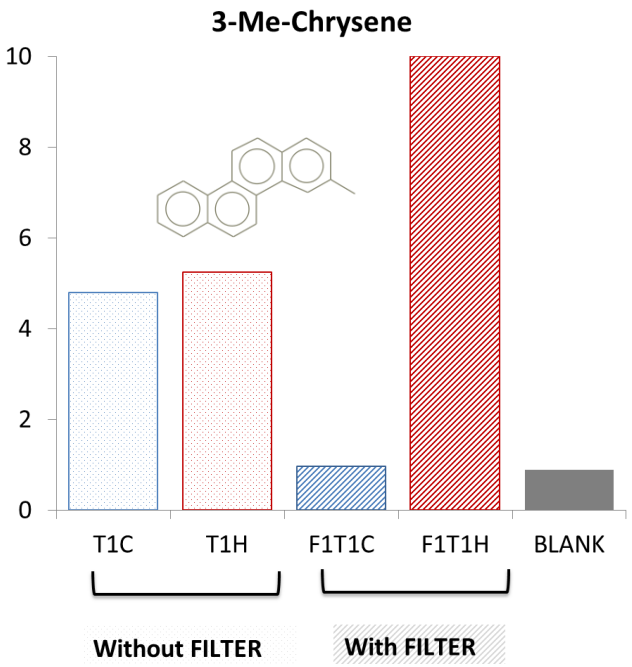
SUMMARY 2-4 RINGS



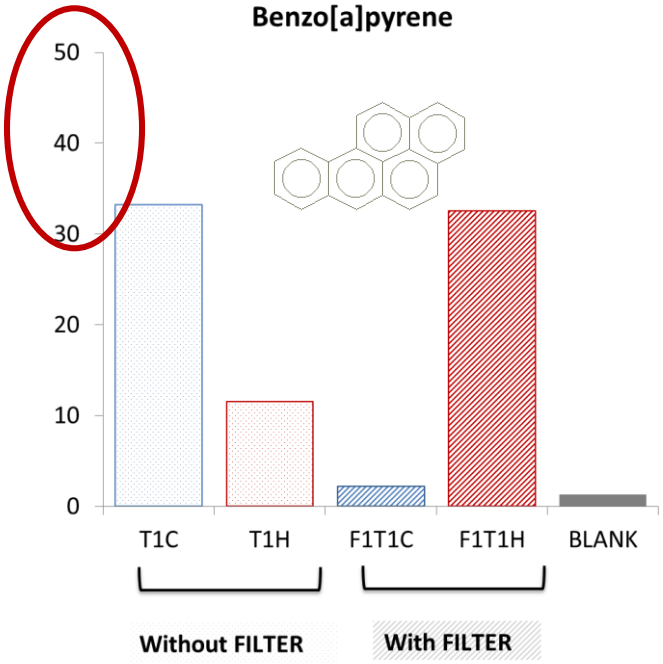
218 °C — Boling point — 404 °C



↓5x



4-5 RINGS

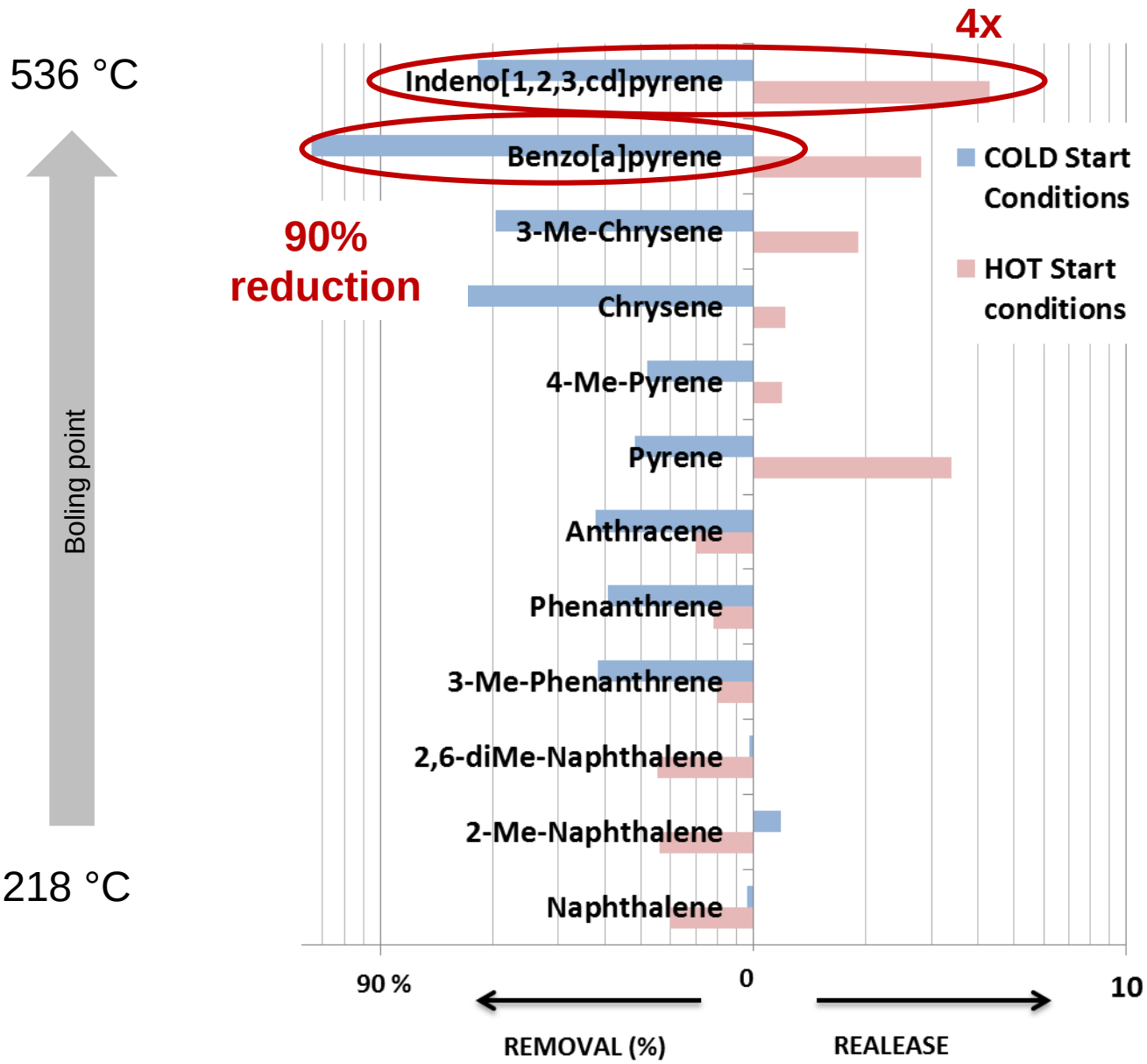


DIESEL EMISSIONS
BENZO(a)PYRENE

78 -92 ng/Nm^3 without filter

< 10 ng/Nm^3 with filter

FILTER EFFICIENCIES



NITRO-PAHS

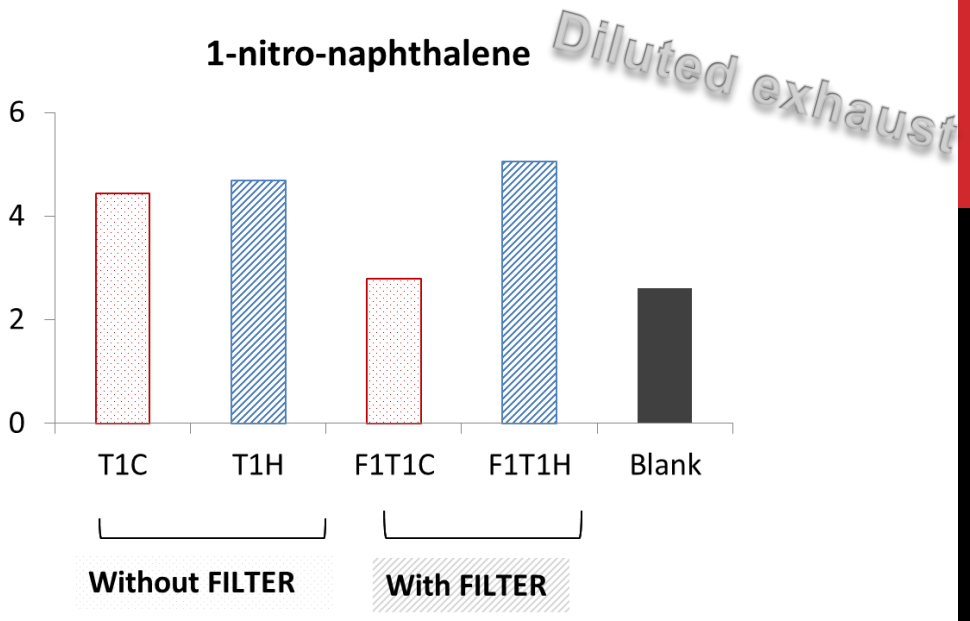
Ambient air levels:

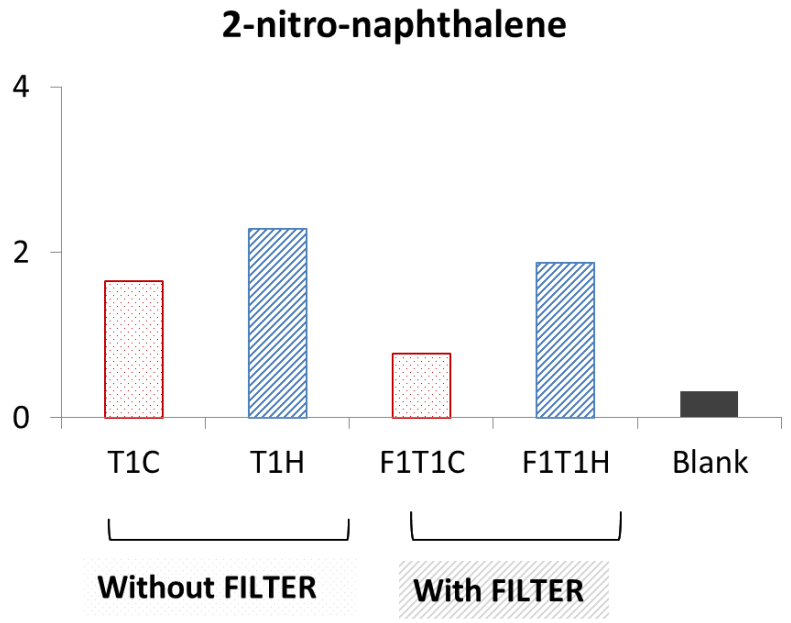
1-nitro-naphthalene: 0.39-5.71 ng/m^3
2-nitro-naphthalene: 0.17-3.1 ng/m^3
6-nitrochrysene: 0.27-1.5 ng/m^3

Health Criteria 229, WHO, 2004

Diesel levels (raw exhaust):

1-nitro-naphthalene
NO FILTERED: 170 - 560 ng/m^3
FILTERED: 4 - 12 ng/m^3
2-nitro-naphthalene
NO FILTERED: 260 - 200 ng/m^3
FILTERED: 17 - 40 ng/m^3





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CONCLUSIONS

PAHs

- The higher the boiling point the better the FILTRATION EFFICIENCY

  COLD start conditions

- The lower the boiling point the higher the **cold start effect**

  without filter

- The higher the boiling point the higher the **hot start** effect

  with filter

PAH storage/release ??
PAH formation ??

NITRO-PAHs

- Ambient levels for diluted exhaust
- Much lower than DIESEL emissions
- More analysis to be done

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THANK YOU

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6th VERT FORUM: Particle Filter Technologies

EMPA Dübendorf, March 20th, 2015