ULTRHAS
ULtrafine particles from TRansportation – Health Assessment of Sources

Influence of photochemical aging on physical-chemical properties of ultrafine particulate matter from the exhaust emissions of a ship diesel engine

Universität Rostock
HELMHOLTZ MUNICH
JOINT MASS SPECTROMETRY CENTRE

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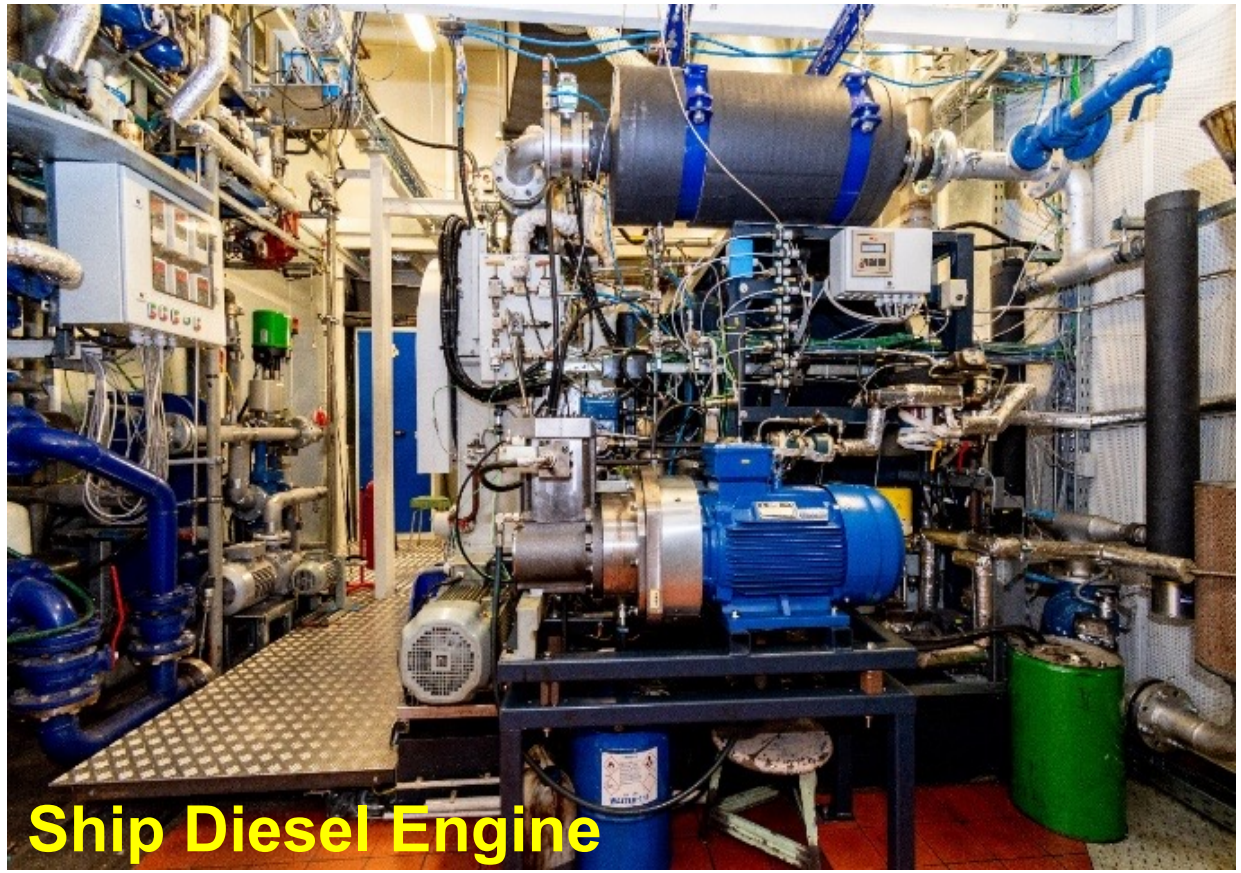
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 955390

NIPH Norwegian Institute of Public Health
HelmholtzZentrum münchen German Research Center for Environmental Health
UNI FR UNIVERSITÉ DE FRIBOURG UNIVERSITÄT FREIBURG
Universität der Bundeswehr München
UNIVERSITY OF EASTERN FINLAND
Universität Rostock Traditio et Innovatio
Finnish institute for health and welfare

Ship Diesel Engine



Parameter	Description / Value
Basics	CR Injection
	4 stroke Diesel
	Distillate, HFO, other
Charge air compression	External
Charge air pressure	Variable 1…4 bar
Rated speed	1’500 rpm
Rated power	80 kW
Bore / Stroke	150 mm / 180 mm
Engine displacement	3.2 l
Compression ratio	Variable (13…16)
Max. injection pressure	1’600 bar

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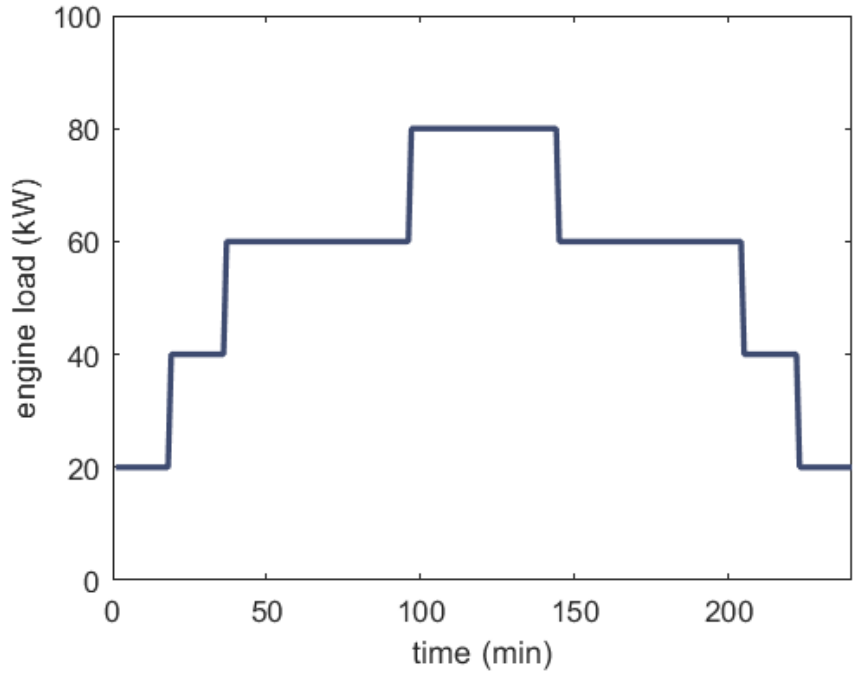
Ship Diesel Engine operating conditions

- Ship diesel engine with two different fuels, Marine Gas Oil (0.015 %S) and Heavy Fuel Oil (0,5 % S), running with Iso cycle 8178 E2



- Aging of exhaust emission aerosols with an oxidator flow tube

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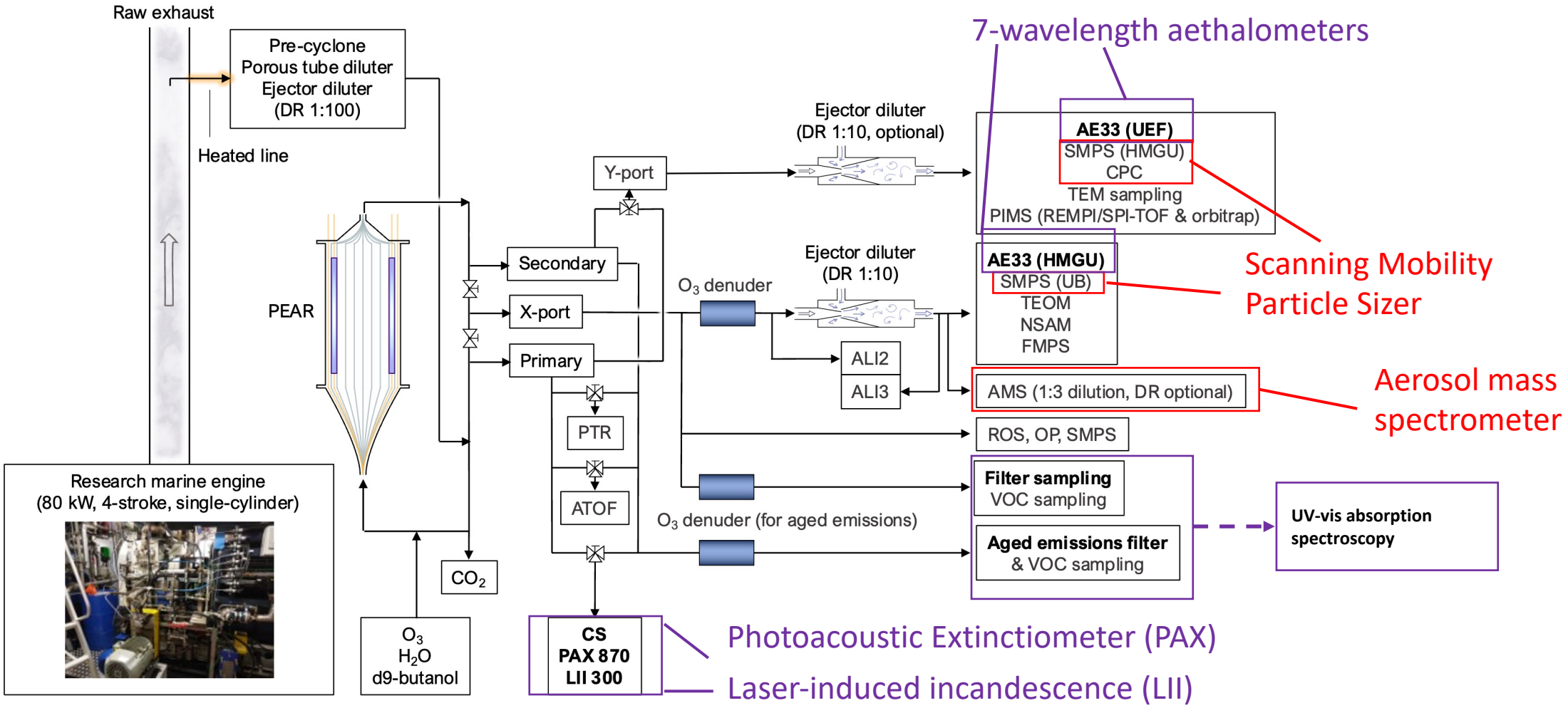
Setup of instruments



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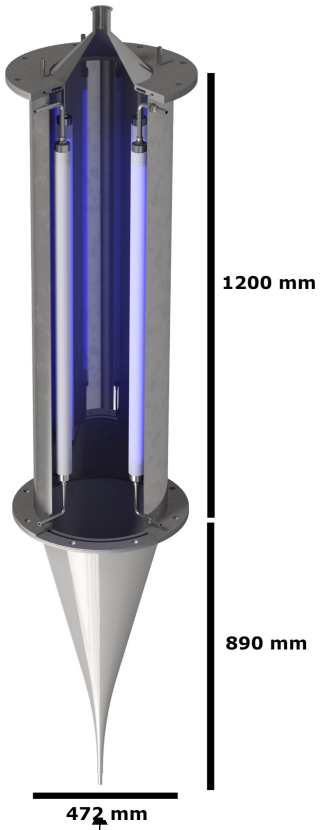
Setup of particle sampling

Marine Gas Oil MGO **0.01 % S**	Heavy Fuel Oil HFO **0.5 % S**

test bench:
1-cylinder 4-stroke
marine engine

UV light
(254 nm)



$$O_3 + UV\,(254\,nm) \rightarrow O\,(^1D) + O_2$$

$$O\,(^1D) + H_2O \rightarrow 2\,OH$$

O_3

H_2O

Diluter
(DR 250)

"aged"

"fresh"

Particle sampling
- 47mm quartz fiber filters

plus

Instrumentation for physical particle characterization

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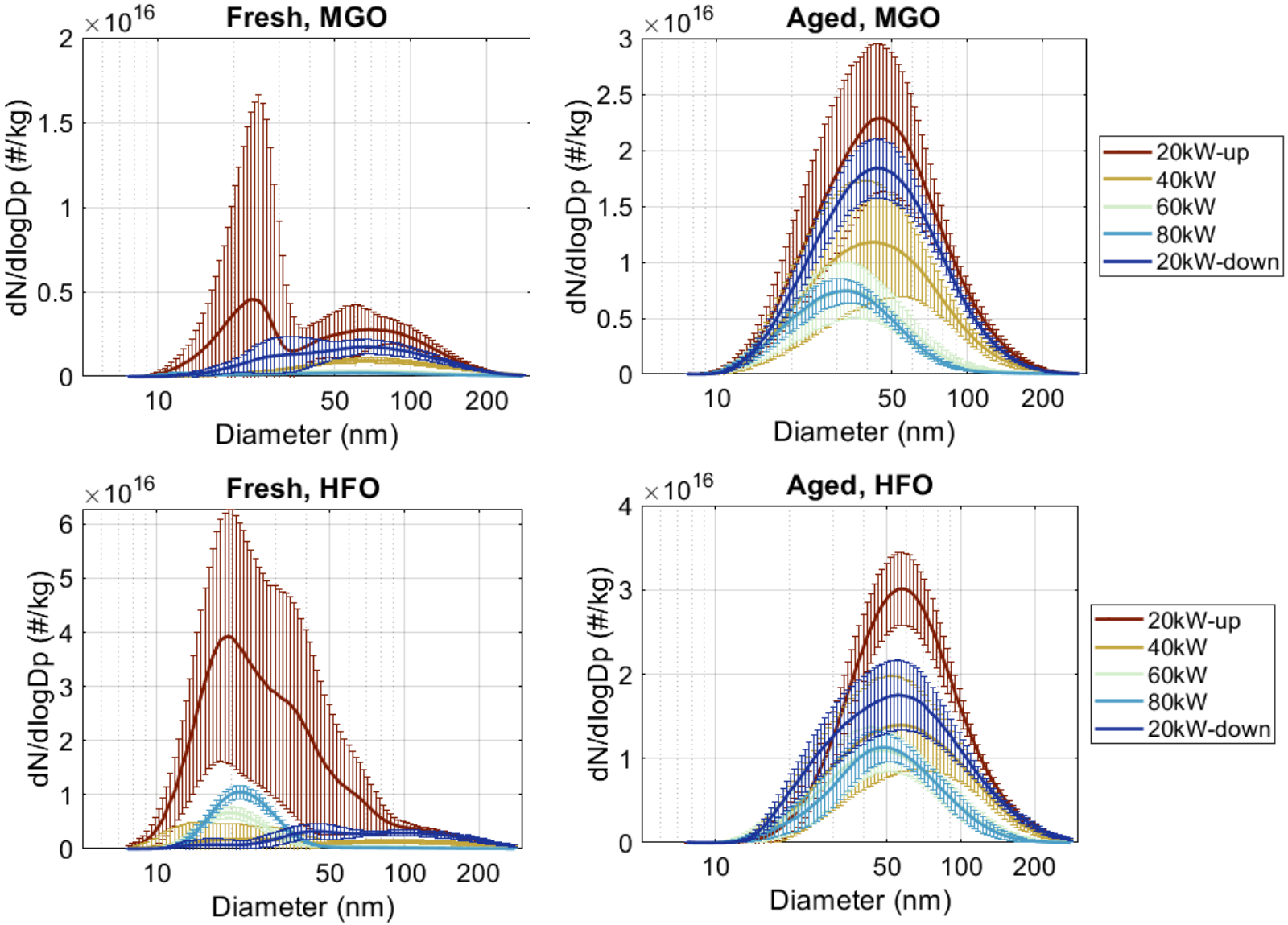
Particle size distributions



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Particle mass and number emission factors

Particle mass is doubled upon aging

Fuel	Mass Emission Factor Fresh [g/kg]	Mass Emission Factor Aged [g/kg]
MGO	0.31 ± 0.03	0.65± 0.04
HFO	0.87 ± 0.06	1.98 ± 0.2

Fuel	Total Number Emission Factor Fresh [#/kg]	Total Number Emission Factor Aged [#/kg]
MGO	$4.9 \cdot 10^{14} \pm 4.8 \cdot 10^{13}$	$5.2 \cdot 10^{15} \pm 6.1 \cdot 10^{14}$
HFO	$3.2 \cdot 10^{15} \pm 7.6 \cdot 10^{14}$	$6.3 \cdot 10^{15} \pm 7.8 \cdot 10^{14}$

For MGO, total particle number increases10-fold upon aging.

For HFO, total particle number is doubled upon aging.

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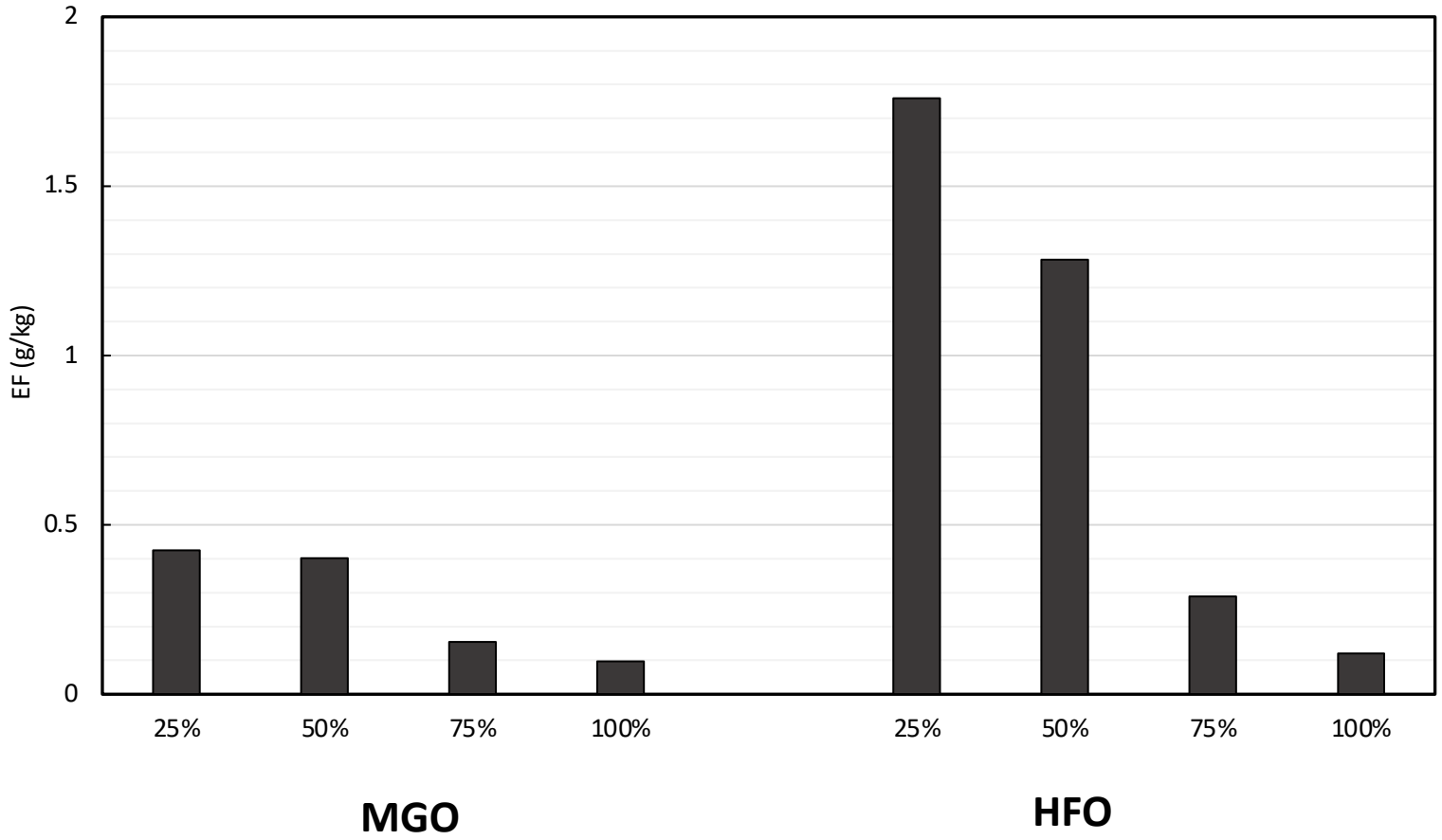
Black Carbon in Fresh Particles

Heavy fuel oil exhibits the triple amount of black carbon particles



Source: Tuukka Kokkola, UEF

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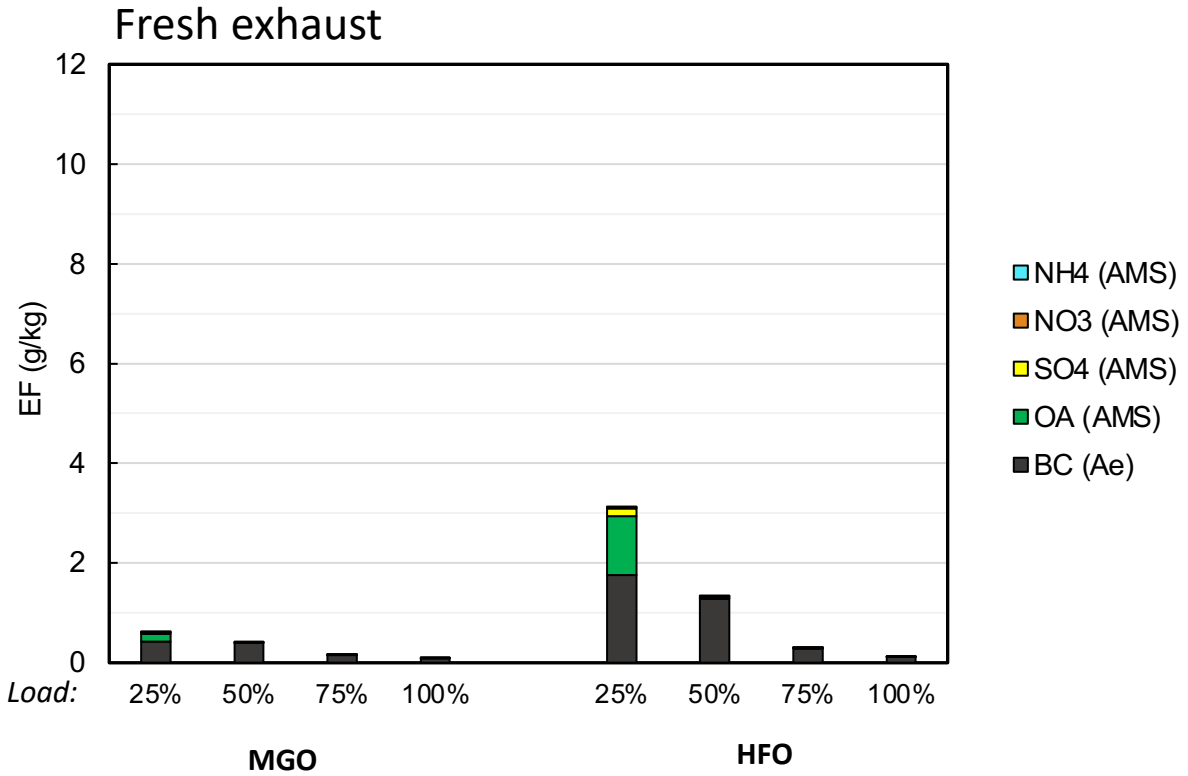
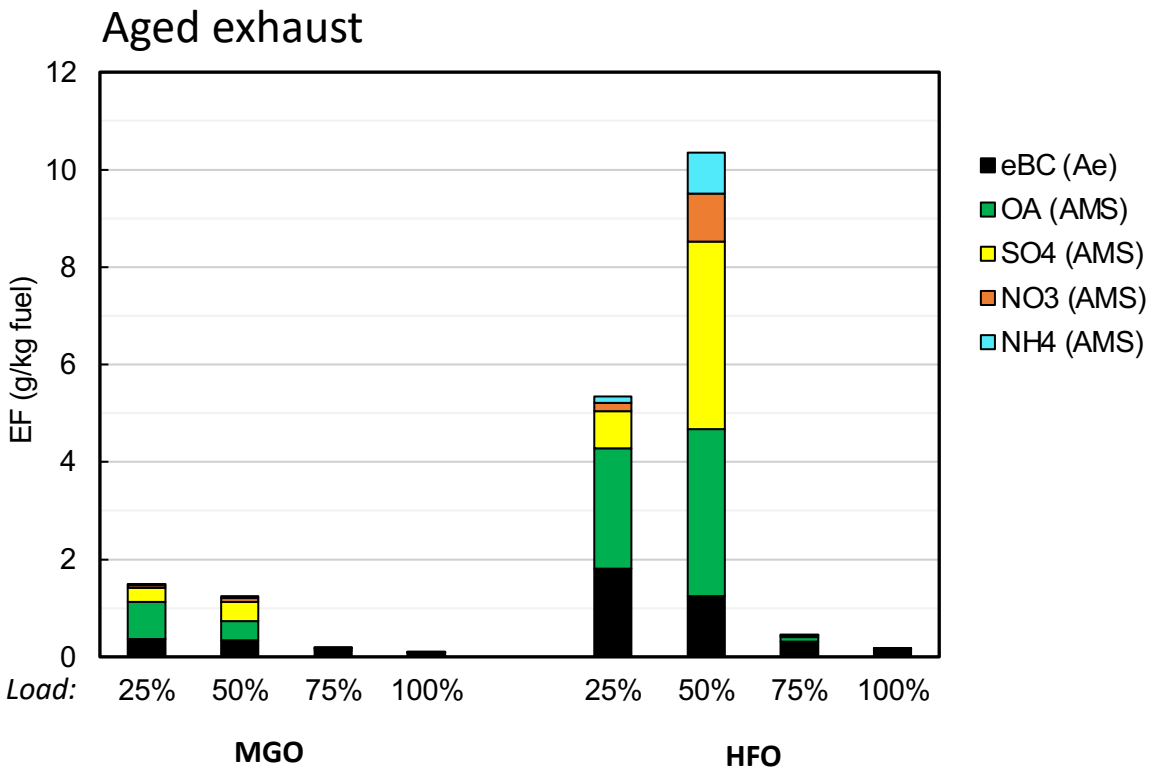
AMS data





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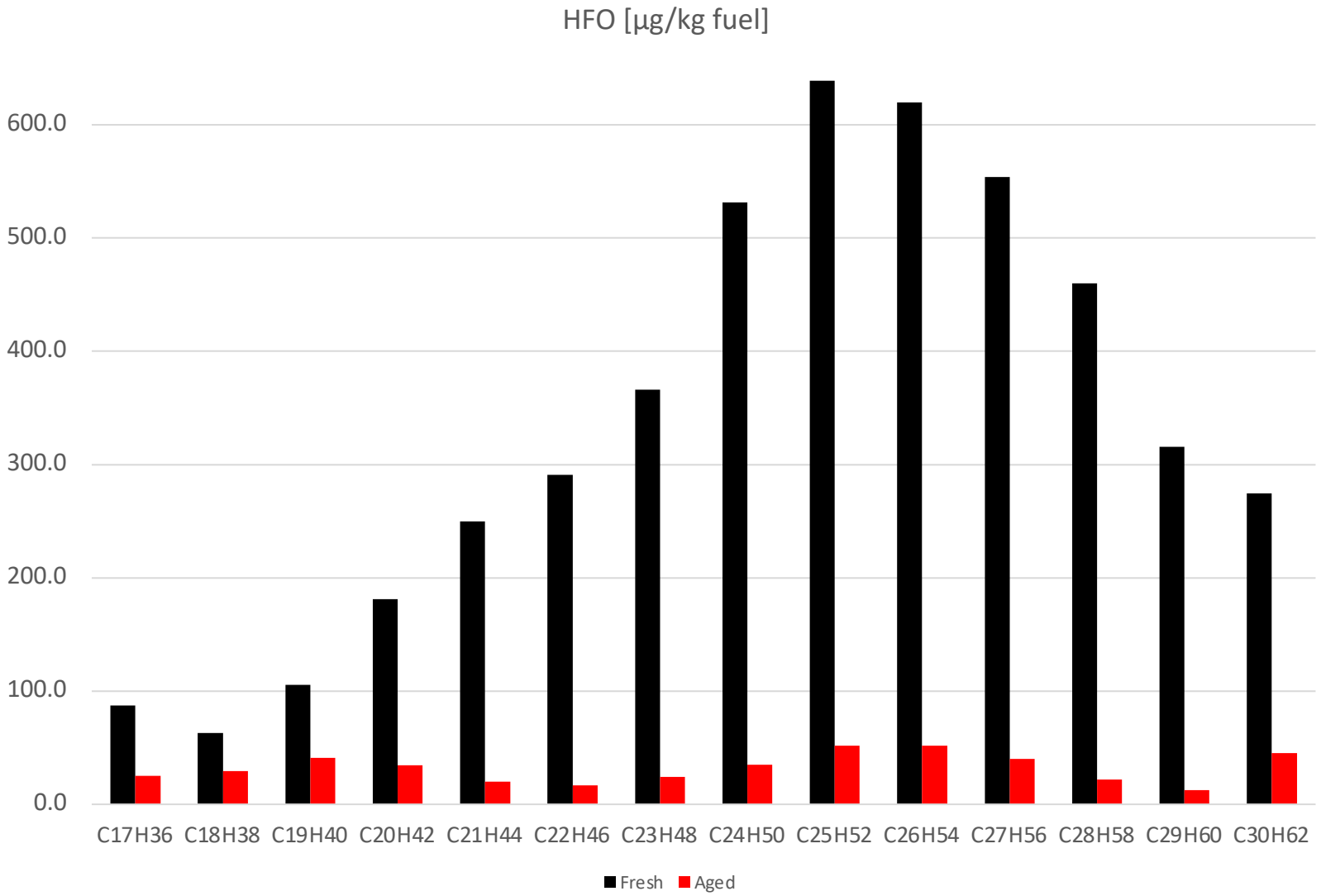
Alkane content of particles HFO (GC/MS)



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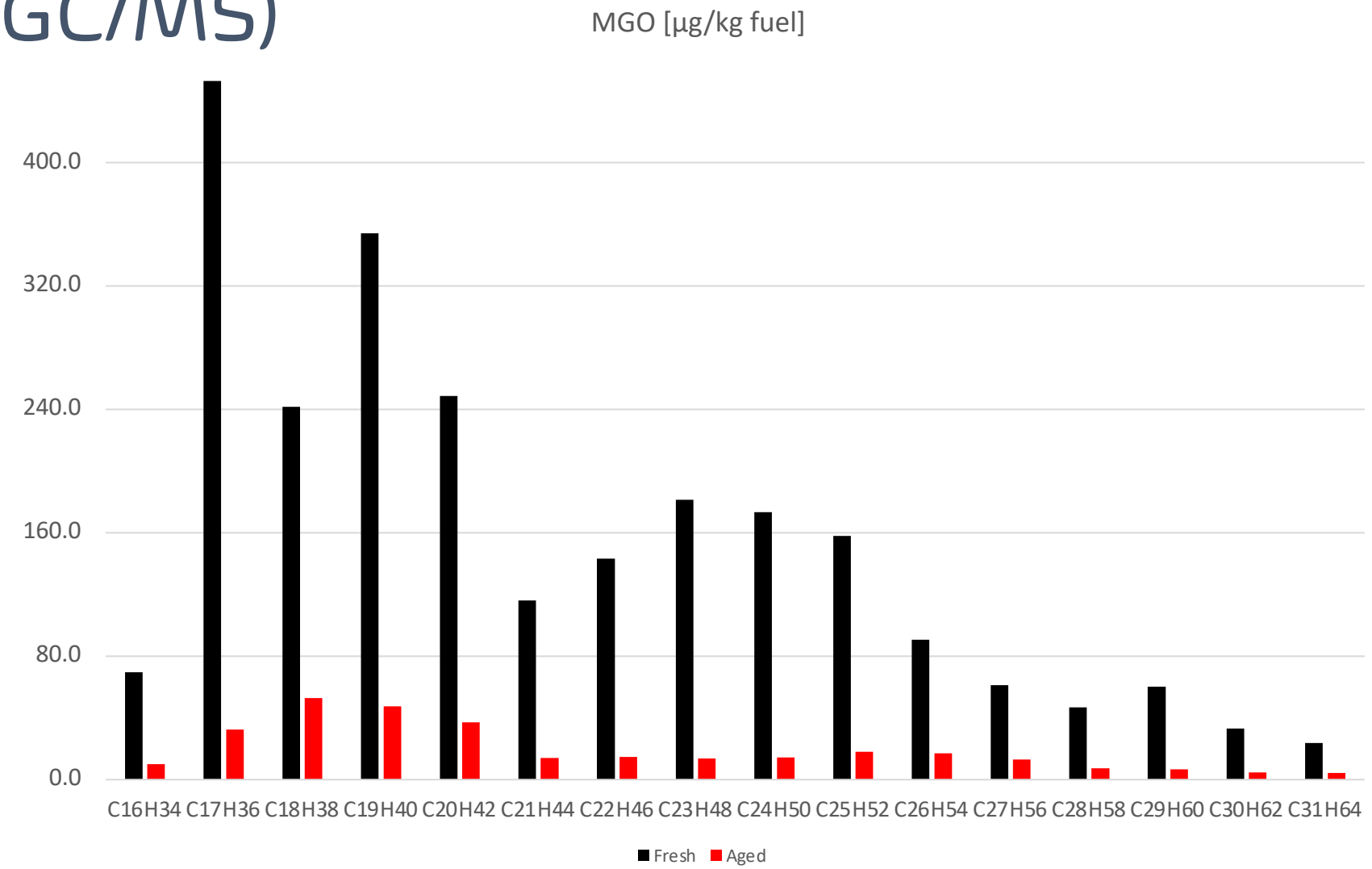
Alkane content of particles MGO (GC/MS)



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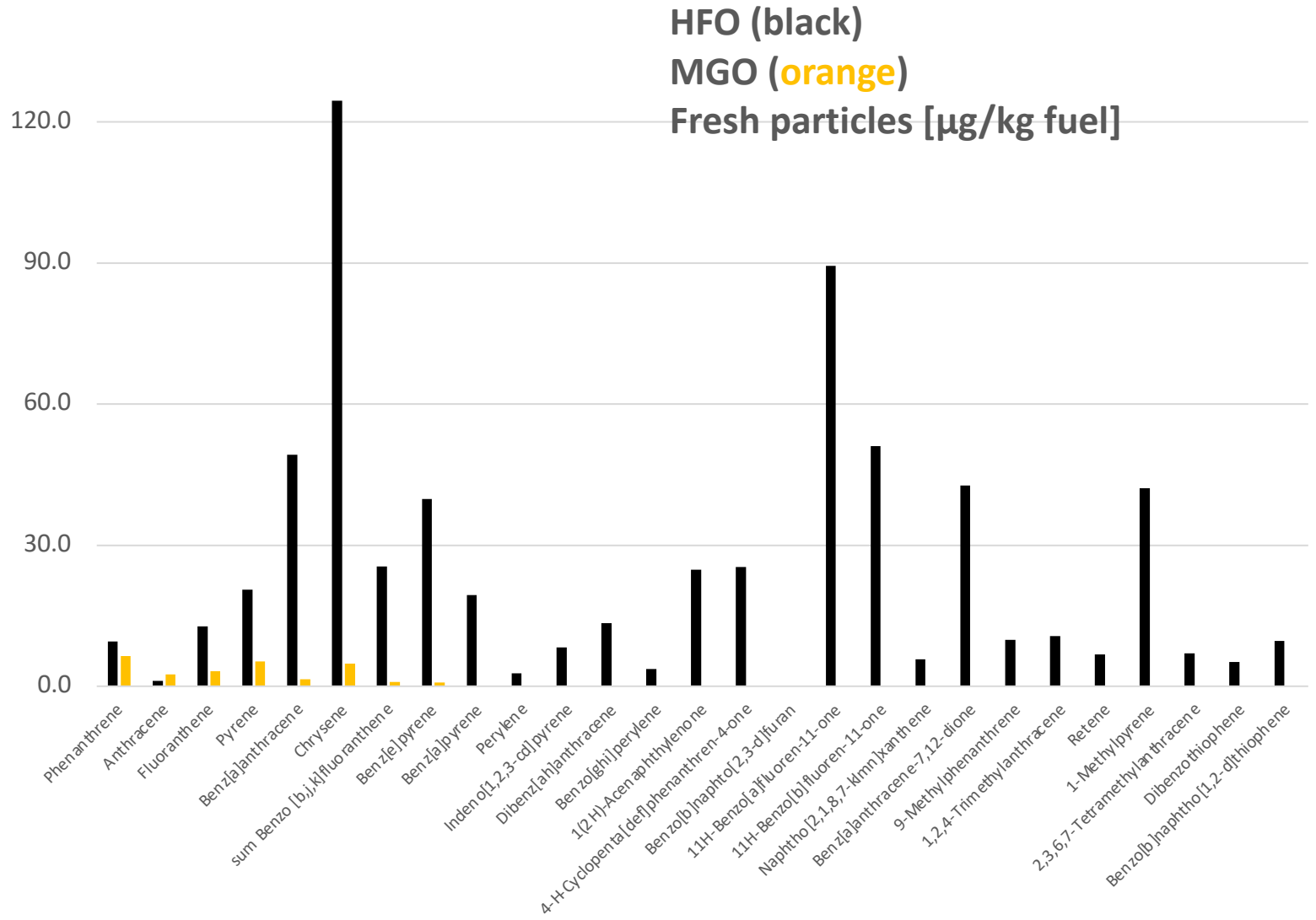
PAH content of fresh particles (GC/MS)



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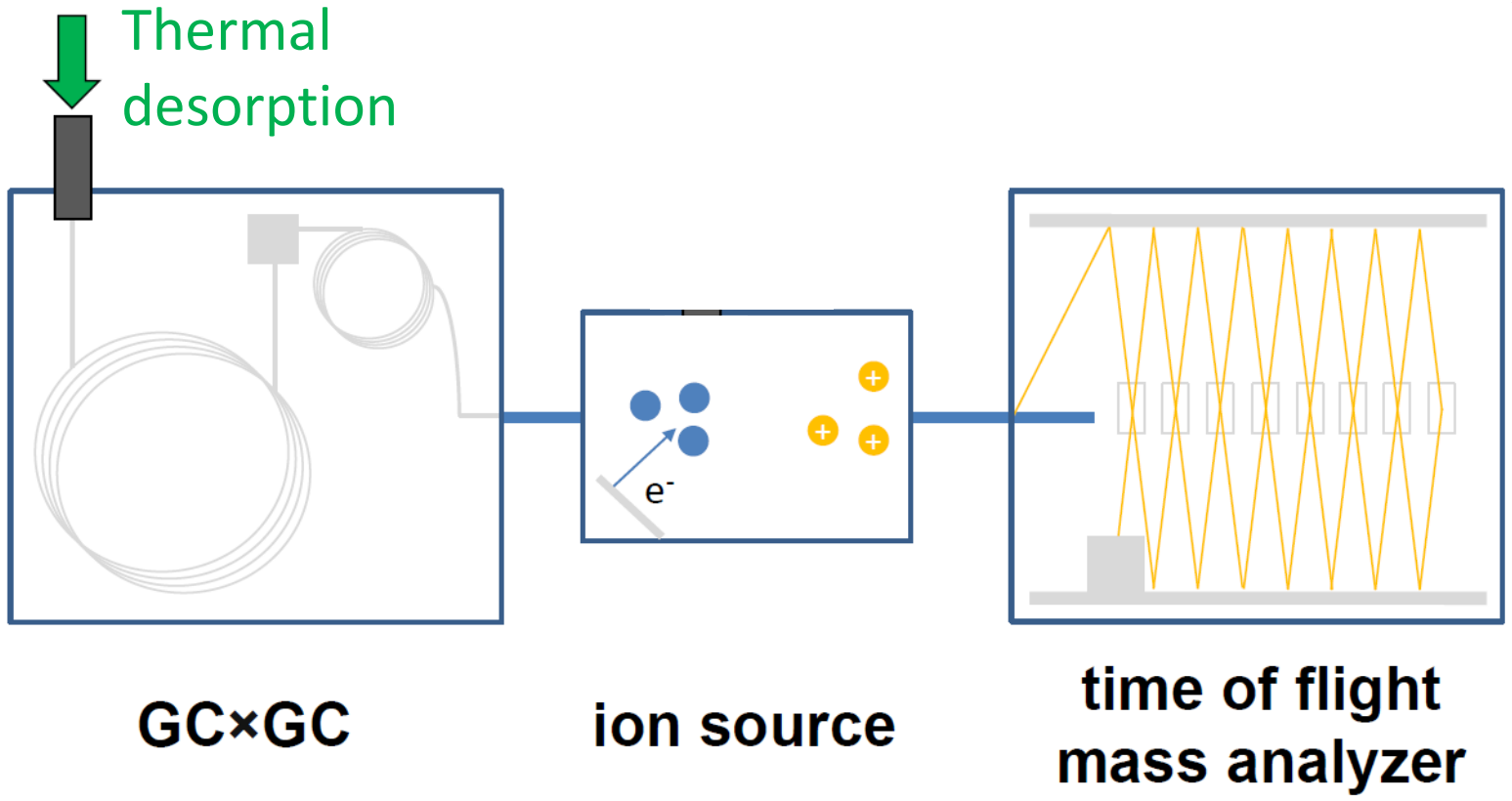
PAH content of particles (GCxGC/MS)



Separation of substances by volatility+polarity

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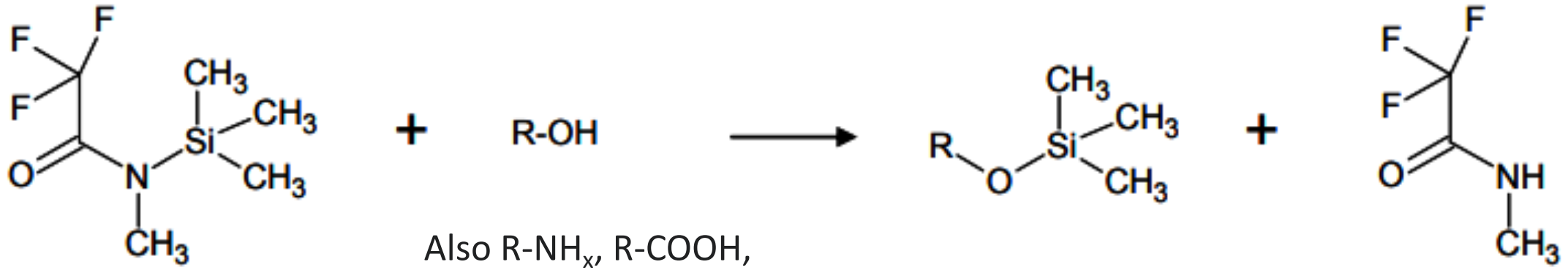
PAH content of particles (GCxGC/MS)

Derivatization using MSTFA

MSTFA = *N*-Methyl-*N*-(trimethylsilyl)trifluoracetamid



Also R-NH_x, R-COOH, R-SH

Trimethylsilyl (TMS) **derivative(s)**

N-Methyltrifluoracetamide (MTFA)

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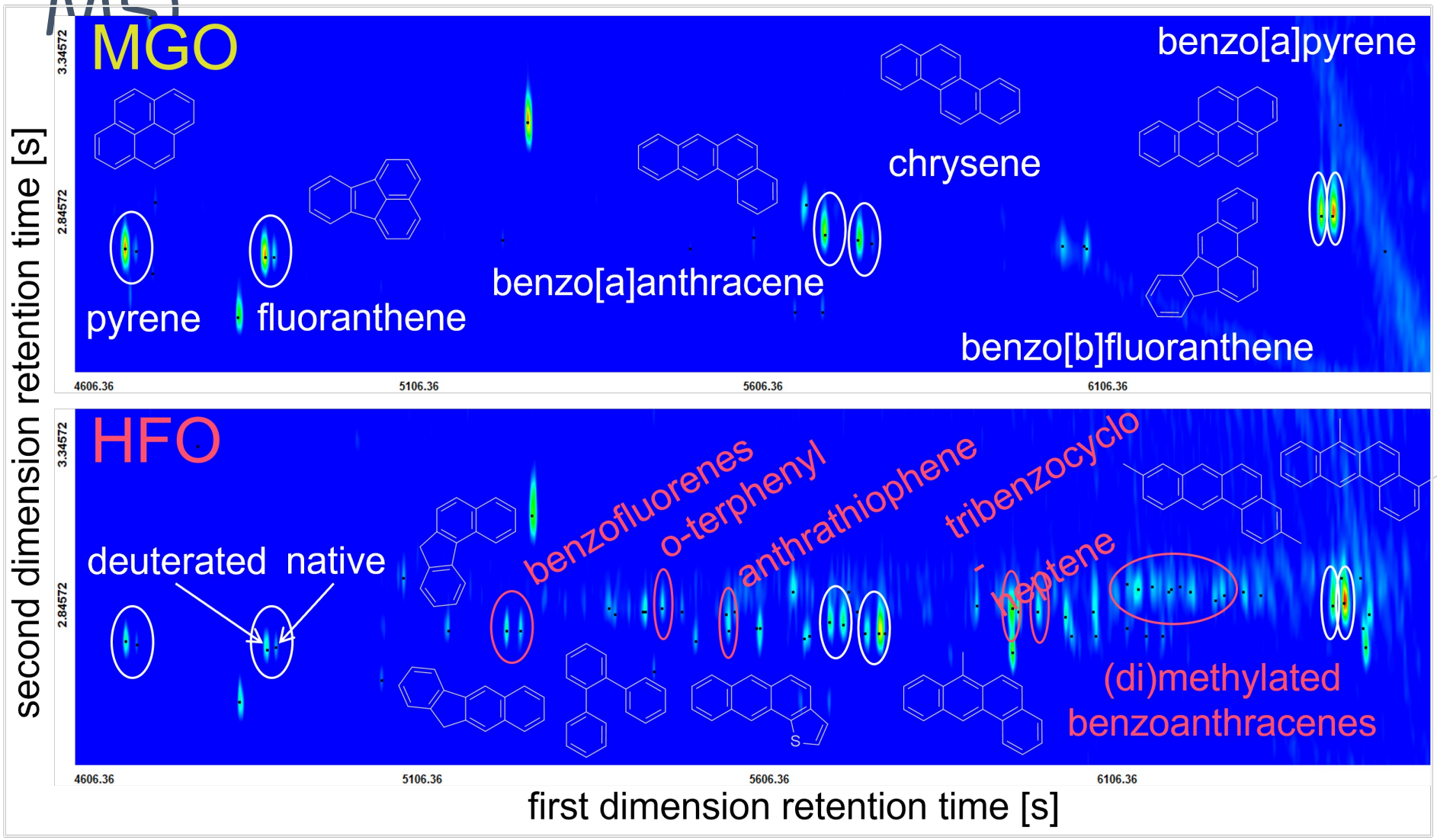
PAH content of fresh particles (GCxGC-MS)



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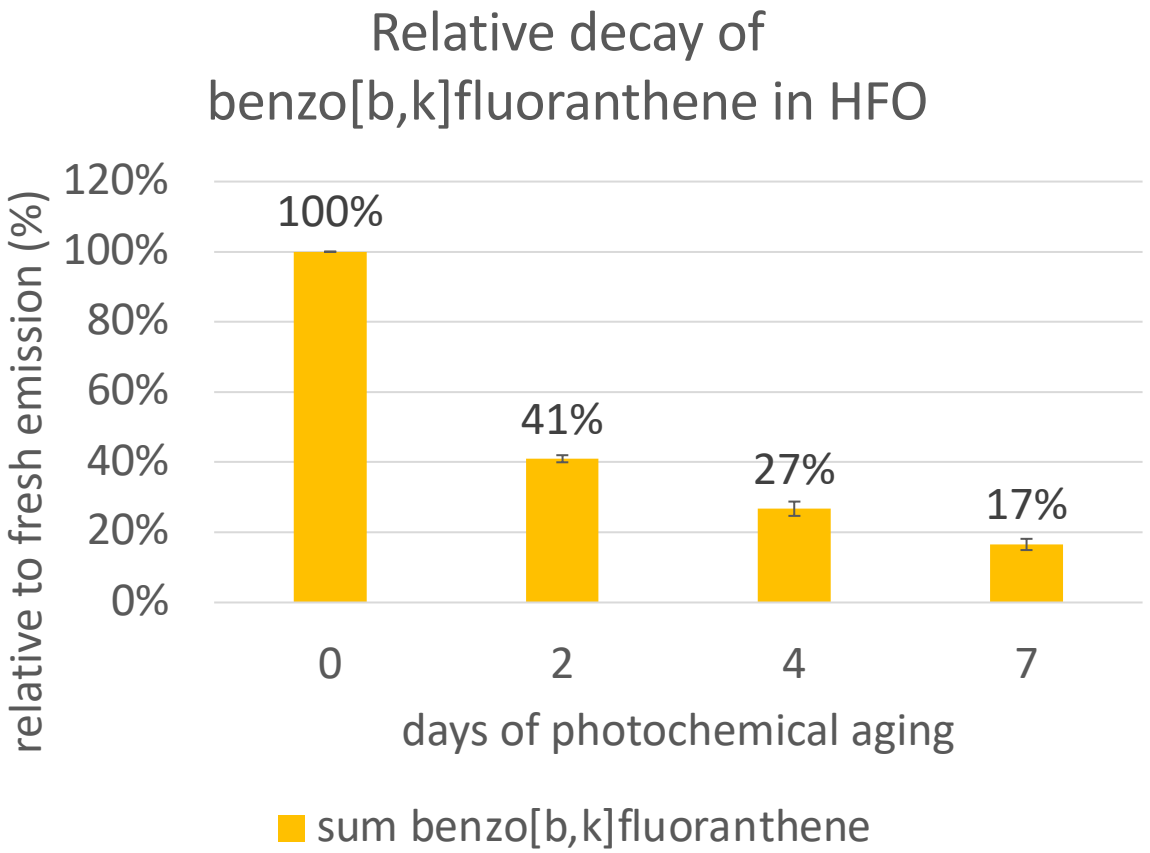
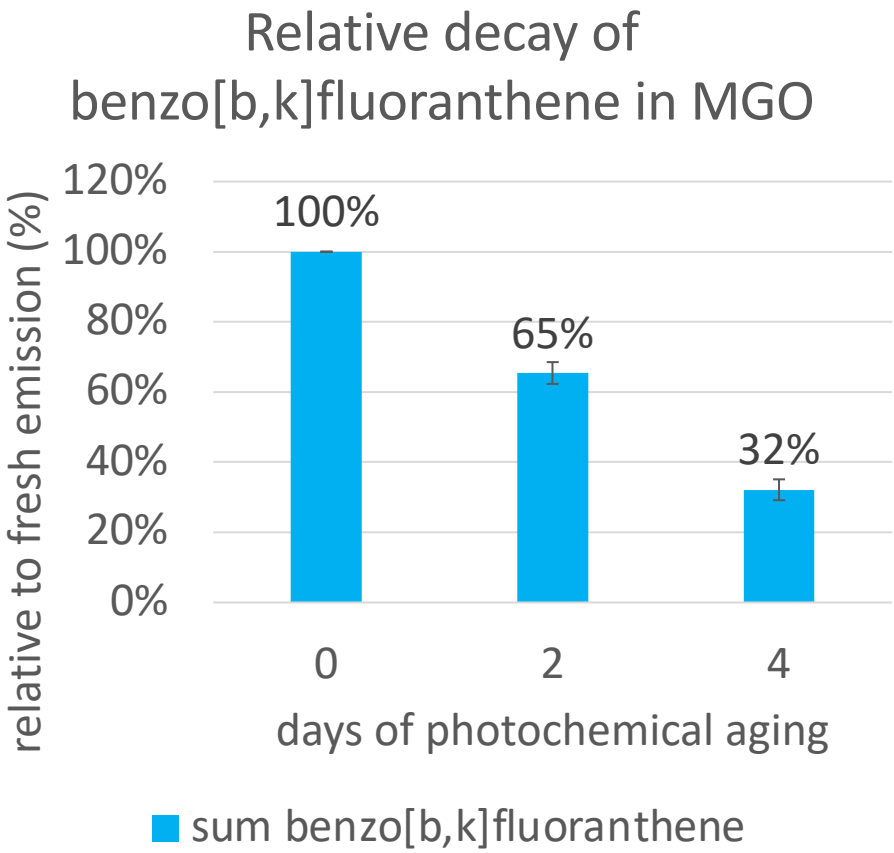
PAH content of aged particles





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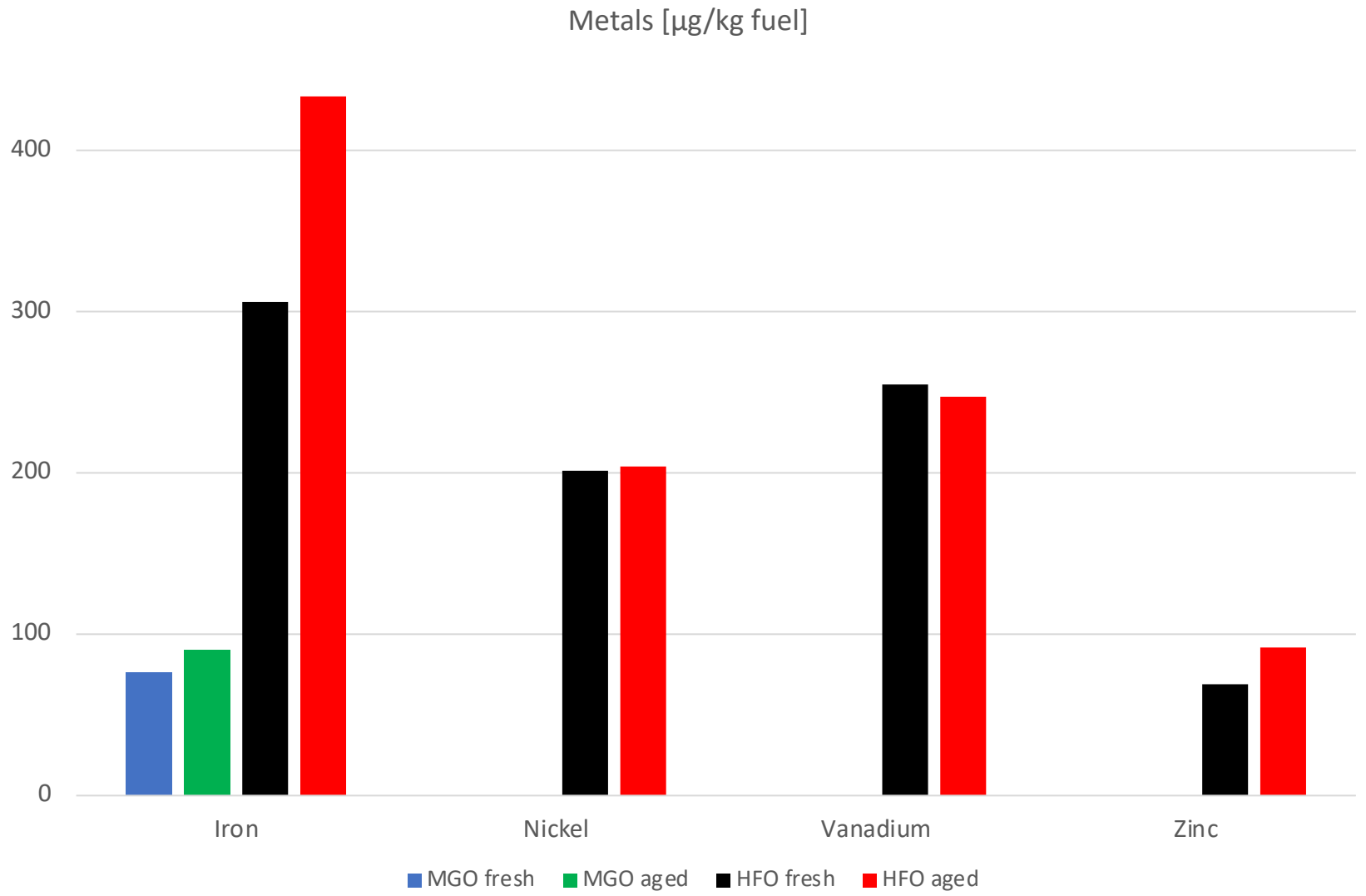
Metal content of particles (ICP-MS)



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Summary and Outlook

- Aging of exhaust aerosol from ship diesel engine combustion has a significant impact on physical metrics of particles.
- Investigated chemical content is very different between MGO and HFO fuel and is also changed by aging.
- Combination with toxicological data will follow.
- Other sources have been investigated (brake wear particles, passenger cars)
  Talks of Johannes Becker and Carsten Neukirchen on Wednesday

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The consortium

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