

Experimental analysis of the influence of current and future marine fuels on particle emissions

SAARUS Project

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Motivation

Project Objectives, Fuels and Research Engine

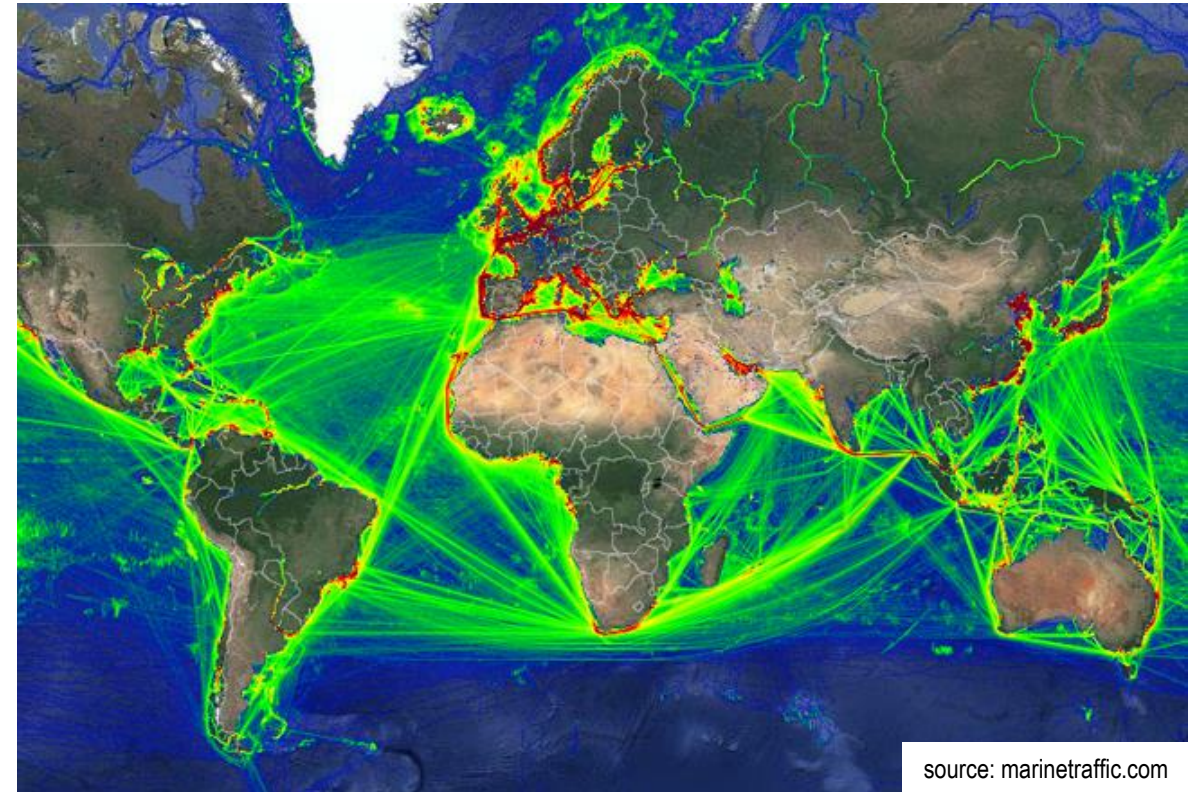
Test Program

Particle Emissions of 1st Measurement Campaign

Outlook and Acknowledgement

Motivation

- Emission limits in international shipping just since 2005
- **No regulation of HC, CO and PM Emission**
 - Only NO_x and SO_x limits
- HFO as global short- and intermediate-term fuel
- Changes in fuel composition according to **Sulphur Cap 2020**
- Potential of scrubber technology for further exhaust gas treatment
 - Decrease of exhaust gas temperature
 - PM-reduction of 65-90 %m up to > 0,5 µm particle size





Project Objectives of SAARUS Research Project

- **Reduction of ship related emissions by optimising and enhancing exhaust gas treatment systems**
 - Optimising SO_x reduction and particle deposition of scrubbers
 - Evaluation and reduction of fine and ultrafine particles / dust (<2,5 µm) downstream scrubber by filter technologies
 - Development of 3D – model for simulation of sulphur reduction and particle deposition inside scrubber
 - Investigation and optimisation of wash water treatment (open & closed loop)

Fuels

- 1 Alternative Fuel: Hydrogenated vegetable oil (HVO)
- Marine gas oil (MGO)
- Compliant heavy fuel oil with sulphur content ≤ 0,5%m (HFO 0,5)
- Standard heavy fuel oil with sulphur content = 2,4%m (HFO 2,4)
- 2 highly aromatic heavy fuel oils (HFO 0,06 and HFO 1,3)





Research Engine: Single Cylinder R&D Engine 1 VDS 18/15 CR

- Capable of running on Diesel, HFO, LSFO, other blends and alternative fuels
- CR injection system with open ECU
- Adjustable charge air and exhaust back pressure
- Variable setup of exhaust gas system



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



Test Program

- ISO 8178-4
- Test cycle E2 for “heavy-duty, constant-speed engines for marine propulsion”

Test mode B-cycle	Speed	Torque	Rated Power Research Engine	Cycle E2
1	Rated speed Research Engine: 1500 rpm	100 %	80 kW	0,2
2		75 %	60 kW	0,5
3		50 %	40 kW	0,15
4		25 %	20 kW	0,15

Analytical Instrumentation

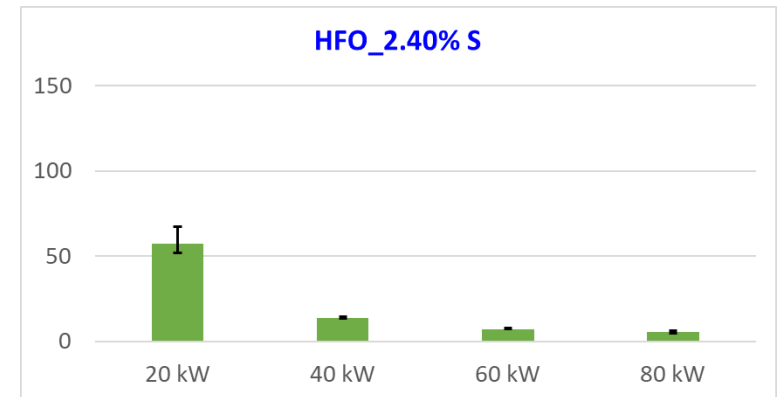
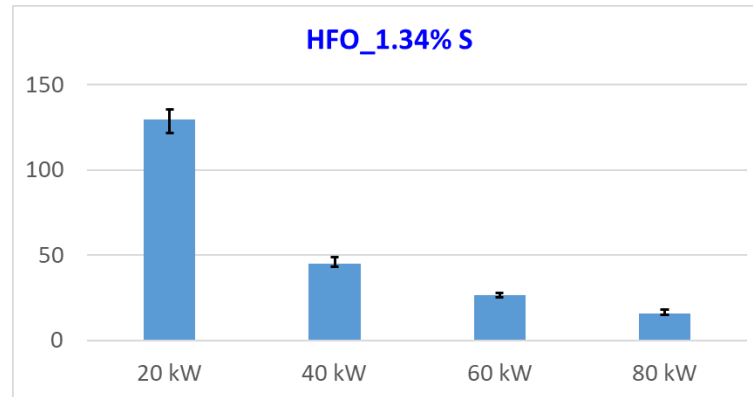
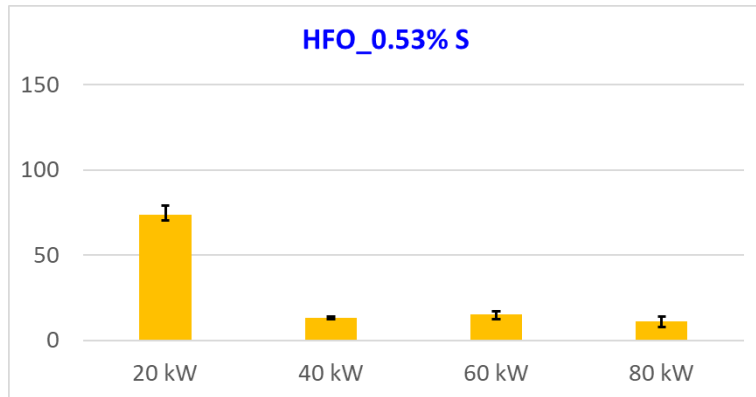
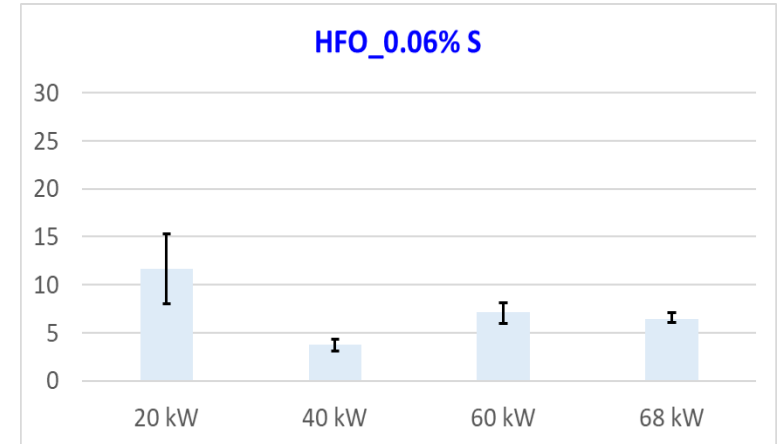
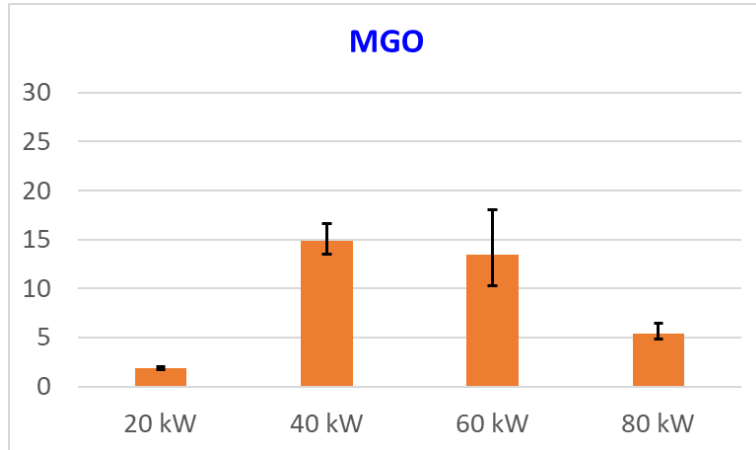
- **Particle analysis in real time**
 - Particle size distribution / Number concentration (SMPS)
 - Black und brown Carbon (Aethalometer)
 - Mass concentration (TEOM, Gravimetry)

- **Particle analysis with filter samples**
 - Organic - Chemical analysis (GCxGC-TOFMS, HR-MS)

- **Fuel analysis (GCxGC-TOFMS)**

Black Carbon

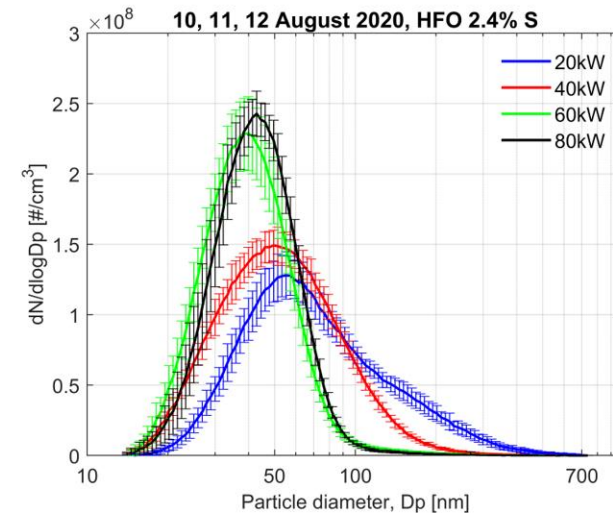
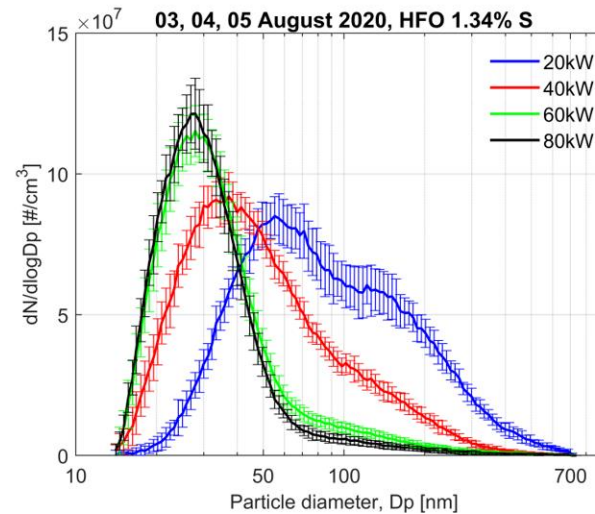
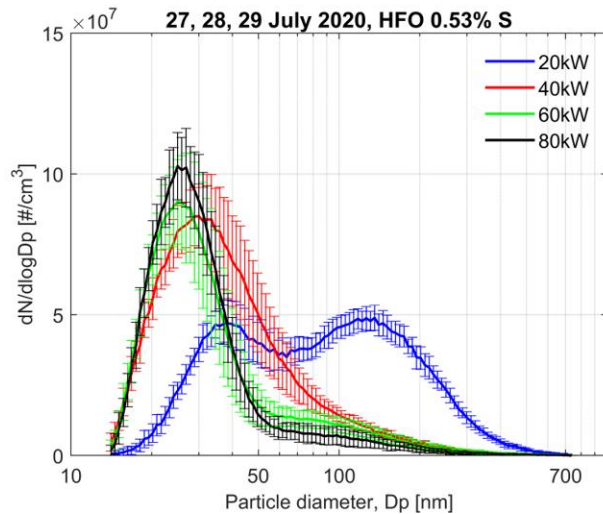
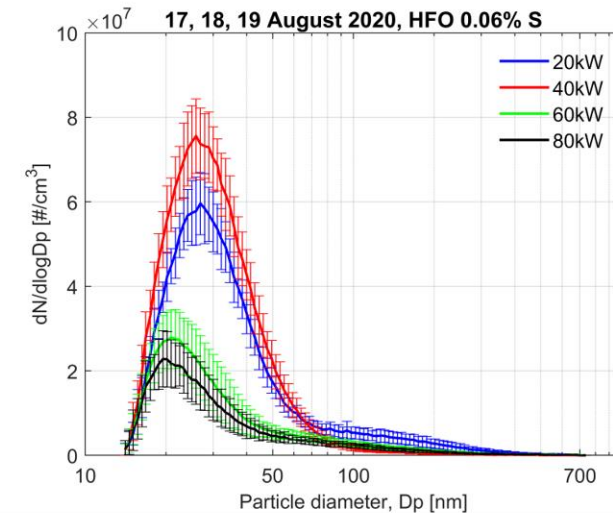
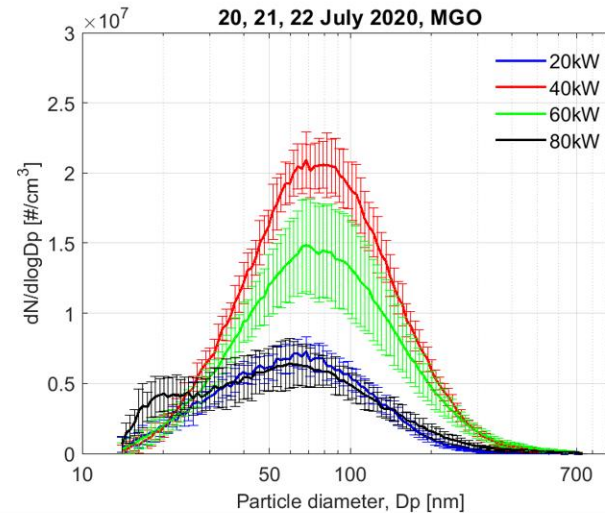
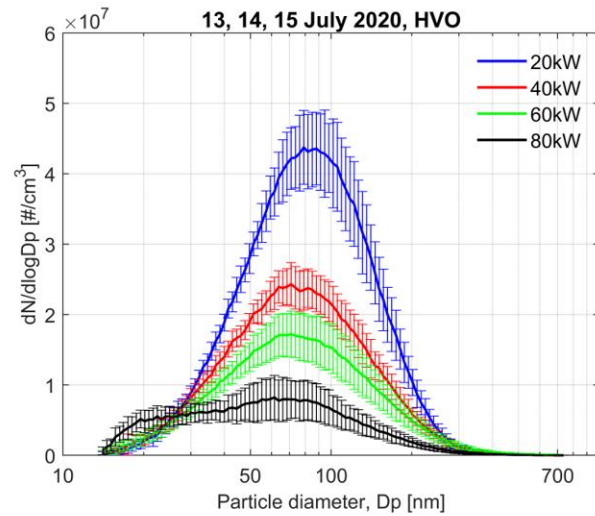
Black Carbon (880 nm) in mg/m³ exhaust gas



Gravimetric and TEOM measurements show the same trends

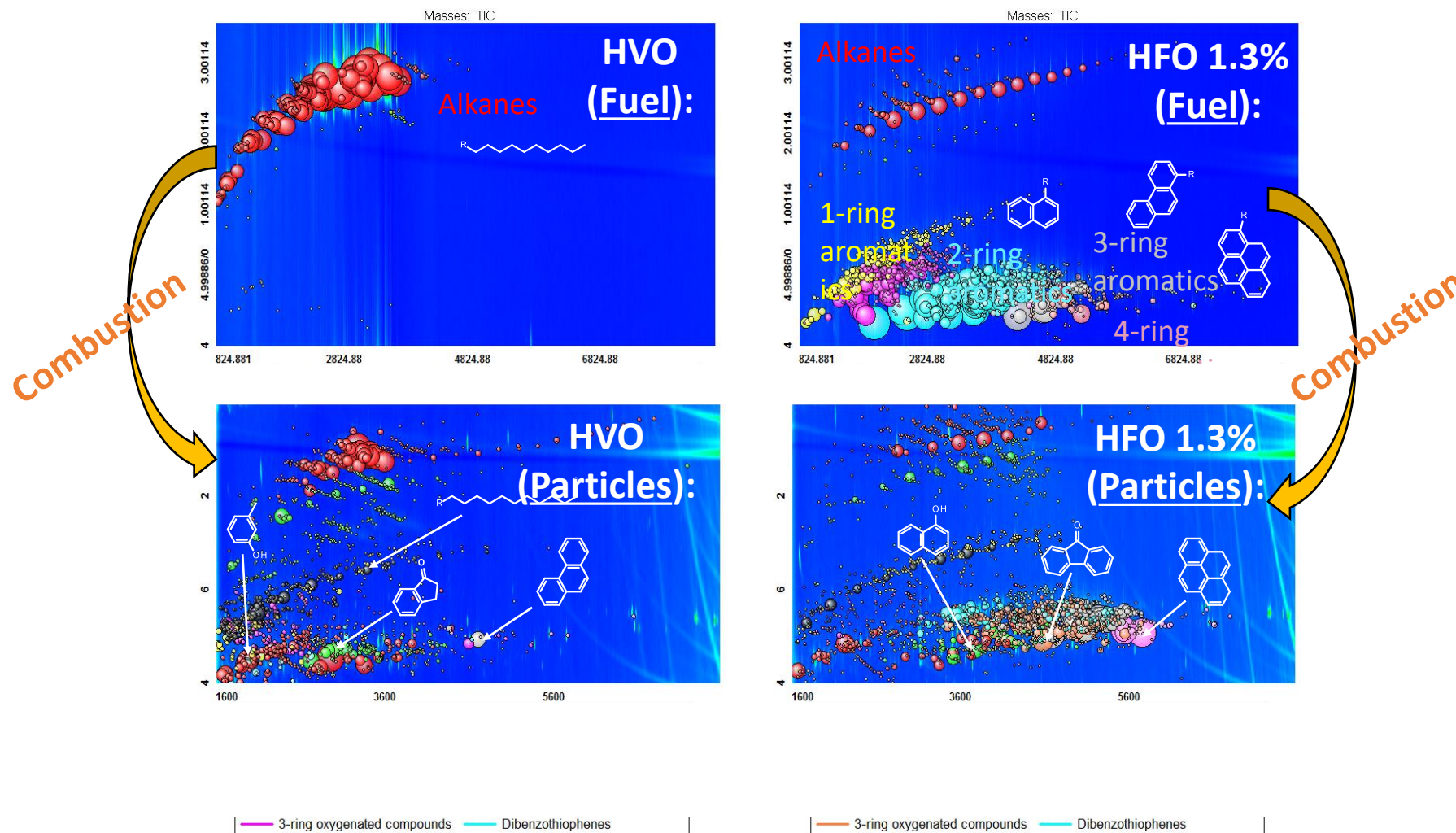


Particle size distributions



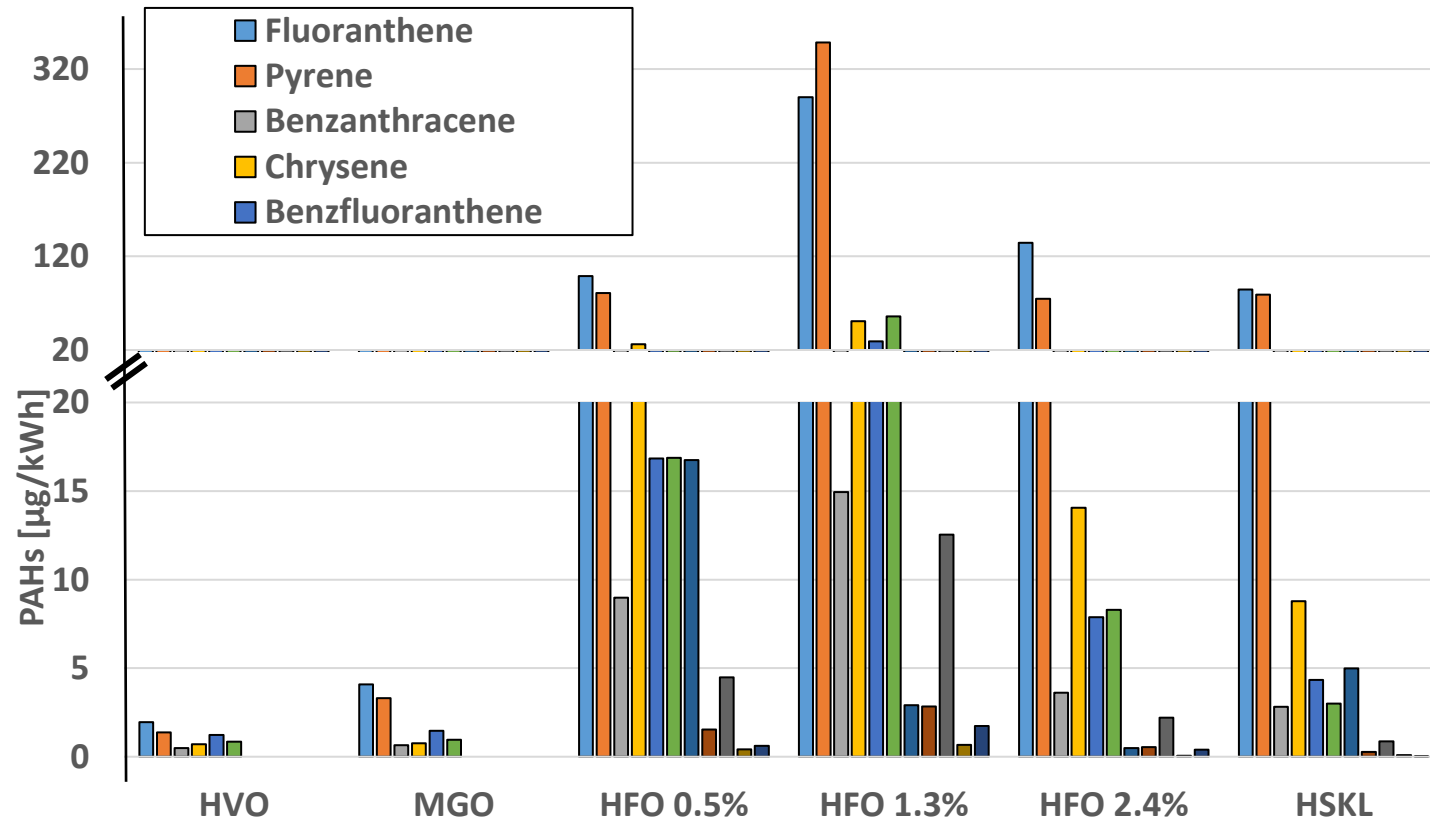


Non-targeted Analysis





Quantitative Analysis



Outlook

■ 2nd measurement campaign in September & October 2021

- 2 engine load points according ISO 8178-4 Cycle E2:

Harbour manoeuvring / costal operation at 25% torque and 1500 rpm

Offshore operation at 75% torque and 1500 rpm

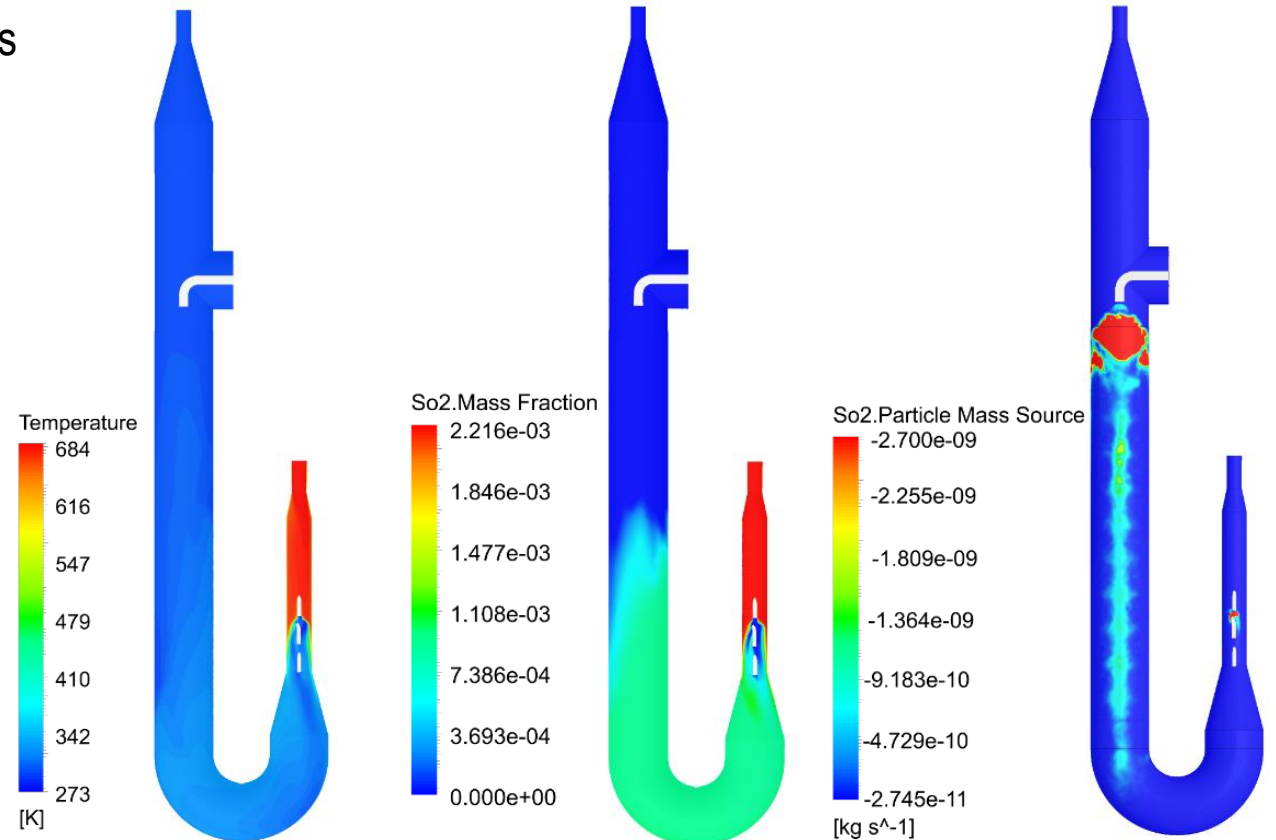
- 3 different scrubber setups: standard spray based without filling material / random packing / structured packing
- 2 filter types: electrostatic precipitator / fabric cartridge filter
- Sample point 1: upstream scrubber / Sample point 2: downstream scrubber / upstream filters / Sample point 3: downstream filters
- Same analytical instrumentation
- Wash water treatment with on- & offline wash water analysis in open and closed loop operation



Outlook

Simulation approach

- Euler-Langrange approach for droplet and particle movement
- SO_x absorption and PM removal by water droplets
- Tool for efficient improvement of the scrubber





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