Impacts of new fuels and emissions controls on emissions of regulated and unregulated pollutants

Insight from onboard measurement campaigns of the SCIPPER and EMERGE projects

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This projects have received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreements Nr.814893 and 874990
Emission Control Areas (ECAS) in EU waters

- Currently three regions

Limits

- 0.1% max fuel S since 1.1. 2015
- Globally outside SECAs 0.5% fuel S limit since 1.1. 2020
- Baltic and North Seas NO\textsubscript{x} Tier III ECAs from 1.1.2021

Developments

- On-going discussion for inclusion of the Mediterranean region as a SO\textsubscript{x} – ECA
- 50 % reduction of greenhouse gas emissions from ships by 2050 compared with 2008 levels
Some options to meet new emission standards:

- Low sulfur fuel and NO$_x$ aftertreatment
- Heavy fuel and both NO$_x$ and SO$_x$ aftertreatment
- LNG
- Other fuels, like methanol, ammonia, electrification, etc.

**SCIPPER & EMERGE**

assessing trade-offs between:

- Air quality & impacts
- Climate change
- Costs for emission controls
- Marine environmental quality & impacts

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SCIPPER Measurement Campaign on RO-PAX ferry (4-stroke diesel engine with SCR)

- On-board exhaust sampling to obtain physicochemical data
  - Assessment of NOx abatement and MeOH fuel
- Testing of onboard compliance monitoring,
  - Selection and testing of equipment & sensors
  - Performance assessment, including uncertainty characterization for SO2, NOx and PM/PN
- Intercomparison of different onboard and remote monitoring techniques
- Verification of monitoring techniques with high-end instruments

12 combinations of fuel – aftertreatment – engine load point investigated

3 mobile laboratories, 15 high-end instruments, 7 in-stack sensors, 5 remote monitoring systems
Measurement campaigns

EMERGE Measurement Campaign on container ship (2-stroke engine equipped with scrubber)

- On-board exhaust sampling to obtain physicochemical data
  - Assessment of HFO & Scrubber, comparison to ULSFO
- Onboard sampling of scrubber water to assess emissions of water contaminants
- Assessment of mass closure between air emissions and water discharges downstream the scrubber

10 sampling points air emissions, 4 combinations of fuel and/or aftertreatment investigated
8 high-end instruments, 5 exhaust conditioning instruments

Offline sampling of exhaust and effluent for further laboratory analyses – 34 exhaust samples, 39 effluent samples, 3 ecotox samples (& replicas)
Insights from the onboard measurement campaigns

Fuels/abatements investigated:

**SCIPPER**
- MGO engine-out
- MGO + SCR, urea off
- MGO + SCR, urea on
- E-methanol: engine-out & postcatalyst, SCR off

**EMERGE**
- HFO engine-out
- HFO downstream scrubber
- ULSFO downstream deactivated scrubber
Gas emissions measurements

RoPAX ferry, MGO/E-methanol, SCR

NOx (g/kg fuel)

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SO2 (g/kg fuel)

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Container ship, HFO/ULSFO, scrubber

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Gas emissions measurements

RoPAX ferry, MGO/E-methanol, SCR

 THC (g/kg fuel)

 CO (g/kg fuel)

Container ship, HFO/ULSFO, scrubber

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 CO (g/kg fuel)

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Gas measurements

RoPAX ferry, MGO/E-methanol, SCR

CH$_4$ (mg/kg fuel)

- post-catalyst MGO, no urea
- post-catalyst MGO, urea
- post-catalyst MeOH, no urea
- engine-out MGO

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Particle measurements

RoPAX ferry, MGO/E-methanol, SCR

- PM composition

Container ship, HFO/ULSFO, scrubber

- PM composition

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PAH measurements

RoPAX ferry, MGO/E-methanol, SCR

- PAH emissions

Container ship, HFO/ULSFO, scrubber

- PAH emissions

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VOC speciation – hydrocarbons and oxygenated VOCs

RoPAX ferry, MGO/E-methanol, post-catalyst

Conteiner ship, HFO/ULSFO, scrubber

NMHCs

Oxygenated VOCs

Aldehydes

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Exhaust aging – secondary particle formation potential

Oxidation flow reactor experiments & aerosol mass spectrometer analyses - RoPAX ferry
Particle size distribution

**HFO upstream scrubber**
- Fresh
- Thermodenuder

**HFO downstream scrubber**
- Fresh_2IR2
- Fresh_2IR5
- Thermodenuder
- Catalytic Stripper + Ejector Diluter

**ULSFO downstream deactivated scrubber**
- Fresh-fuel transition
- Fresh_2IR2
- Fresh_2IR3
- Thermodenuder
- Catalytic Stripper + Ejector Diluter
Conclusions

- **SCR**: Catalyst with urea reduced not only NOx but also CH4 and other organic species, both volatile and non-volatile. While CH4 is reduced only under urea injection, the non-methane organic species (THC, VOC, PAHs, PM-bound OC) were reduced also when urea is switched off.

- **Methanol fuel**: Reduction of a number of emitted species was observed for the MeOH compared to MGO fuel: NOx by 70%, CH4 by 40%, CO by 30%, SO2 by 50%, PM mass and EC by 80% and OC by 70% and PAHs by 40%-60%. Decrease of NMVOCs and NMHCs emissions observed but at the same time an increase of THC emissions, most likely due to emission of HCHO.

- **HFO fuel with scrubber**: Emissions of PM downstream the scrubber were significantly higher compared to emissions from ULSFO or MGO fuel observed during SCIPPER and EMERGE campaigns. Large difference in composition of PM emitted from HFO and ULSFO and from MGO. Findings regarding emission of PAHs are not conclusive due to large variation of the measured emissions most likely associated with influence of engine load on emissions. The upstream-scrubber emissions of PAHs are significantly higher than engine-out emissions from MGO fuel on the Ro-Pax ferry.

- **Impact of scrubber aftertreatment**: No reduction of PM or its compounds (soot, OC, sulphate) observed over the scrubber. Significant reduction of PAH observed.
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Anna-Lunde Hermansson (Chalmers)

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