INTERNATIONAL MARITIME ORGANIZATION

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Agenda item 7

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CONSIDERATION OF THE IMPACT ON THE ARCTIC OF EMISSIONS OF BLACK CARBON FROM INTERNATIONAL SHIPPING

Black Carbon emission measurement results for 4-stroke marine diesel engines, using various fuels, and with and without scrubber

Submitted by Finland

SUMMARY

Executive summary:	This document contains information on Black Carbon measurement results for 4-stroke marine diesel engines, using various fuels, and with and without scrubber
Strategic direction:	Number to be assigned after A30
High-level action:	Number to be assigned after A30
Output:	Number to be assigned after A30
Action to be taken:	Paragraph 12
Related documents:	PPR 2/21; PPR 4/9/2, PPR 4/9/3 and PPR 4/INF.7

Introduction

1 At its second session, the Sub-Committee, having noted the need for Black Carbon (BC) measurement studies to gain experience with the application of the definition and measurement methods, invited interested Member Governments and international organizations to initiate, on a voluntary basis, BC measurement studies to collect data. At the same time, information of different potential options to reduce BC is gathered.

2 Concerning the voluntary BC measurement project SEA-EFFECTS BC in Finland, documents PPR 4/9/2, PPR 4/9/3 and PPR 4/INF.7 were submitted by Finland to PPR 4. In document PPR 4/9/2, it was concluded that the BC emission measurement results were similar using Filter Smoke Number (FSN), Photoacoustic Spectroscopy (PAS) and Multiangle Absorption Photometry (MAAP) in spite of the different measurement principles of the used methodologies. When the tests were carried out in a research laboratory for an old diesel engine, dependences were found between BC emissions with regard to fuel used and engine loads, but reduced fuel sulphur content did not necessarily reduce BC emissions. The elementary carbon (EC) analysis was found to be challenging particularly for the samples from

ships using residual marine fuels. In document PPR 4/9/3, it was concluded that MAAP measurement method designed for the ambient BC measurements requires high dilution ratios (DRs) to keep BC concentrations within the measurement range when diesel engine exhaust is measured. High DRs require special instrumentation and experienced personnel. Uncertainty due to the DR is directly reflected in the BC results. Due to these reasons, the parameters of MAAP measurements need careful inspection for reliability of the results; MAAP is not considered to be practical for onboard measurements. Pre-treatment may alleviate the bias between different BC measurement techniques, however, at the cost of complexity of the test set-up. In document PPR 4/INF.7 a summary was presented on the CIMAC article (Aakko-Saksa et al. 2016) concerning the voluntary SEA-EFFECTS BC project in Finland.

3 In this document, new information on the BC emission measurement results from two onboard ship measurement programs are provided together with the BC emission measurement results from the laboratory engine presented in PPR 4. Altogether, the BC measurements cover four 4-stroke marine engines at various engine loads. The effect of fuel quality on BC emissions from ship diesel engines is demonstrated by using fuels with different sulphur contents from below 0.1% to up to 2.5%. Furthermore, the effect of scrubber on the BC emissions is presented, based on the onboard measurements conducted on two ships. The BC emission measurement results are based on the FSN methodology.

Measurement campaigns

4 The SEA-EFFECTS BC project included two measurement campaigns conducted by VTT Technical Research Centre of Finland, Finnish Meteorological Institute and Tampere University of Technology. The following BC emission measurements were conducted:

.1 On board a modern cruising ship with a SCR catalyst and a hybrid scrubber. BC emissions from two engines were measured at 40% and 75% engine loads. In most measurements residual fuel with 0.65% sulphur content was used, and for one engine also with fuel below 0.10% sulphur content (Timonen et al. 2017).

.2 In laboratory, BC emissions of a 1.6 MW marine engine were measured at 75% and 25% engine loads using various fuels. For these tests the BC emission measurement results with fuels containing 2.2% and below 0.1% sulphur are presented (Aakko-Saksa 2016; Aakko-Saksa et al. 2017).

5 The EnviSum project measurement campaign was conducted by VTT Technical Research Centre of Finland, Finnish Meteorological Institute and Tampere University of Technology on board a RoPax ship. BC emissions were measured from one of its main engines. The ship was equipped with a seawater scrubber. In most measurements residual fuel with 1.9% sulphur content was used, but BC emissions with fuel containing below 0.10% sulphur was also measured. BC emissions were measured for various engine loads, although only preliminary results obtained at 65% load are presented (Aakko-Saksa et al., in preparation).

Results

6 The measured BC emissions were low, from **0.09 to 0.16 g/kg fuel**, for the 4-stroke marine engines at engine loads from 40% to 75% using residual fuels in the onboard ship measurements (three engines) and in the laboratory measurements (one engine) (figure 1). A higher level of BC emissions was observed for an old engine at 25% than at 75% engine load in the laboratory measurements.

7 The BC emissions were slightly higher for distillate fuel with sulphur content less than 0.10% than for the residual fuel at 40% engine load in the onboard measurements of one ship (Ship A, engine 1 in figure 1), while the difference between residual and distillate fuels was not significant for the other ship (Ship B in figure 1). The diesel engines of both ships were equipped with electrical control systems. For the old laboratory engine, the BC emissions were higher for the residual fuel at 75% load than for the distillate 0.10% S fuel, while at 25% engine load difference in the BC emission between these fuels was not significant. The laboratory engine was equipped with a mechanical injection system.

8 Seawater or hybrid scrubber did not significantly affect the BC emission (or BC reduced only slightly) based on the measurements conducted at the two ships. However, in addition to reducing the SO_X emissions, scrubber did also reduce particulate matter (PM) and polyaromatic hydrocarbon (PAH) emissions.

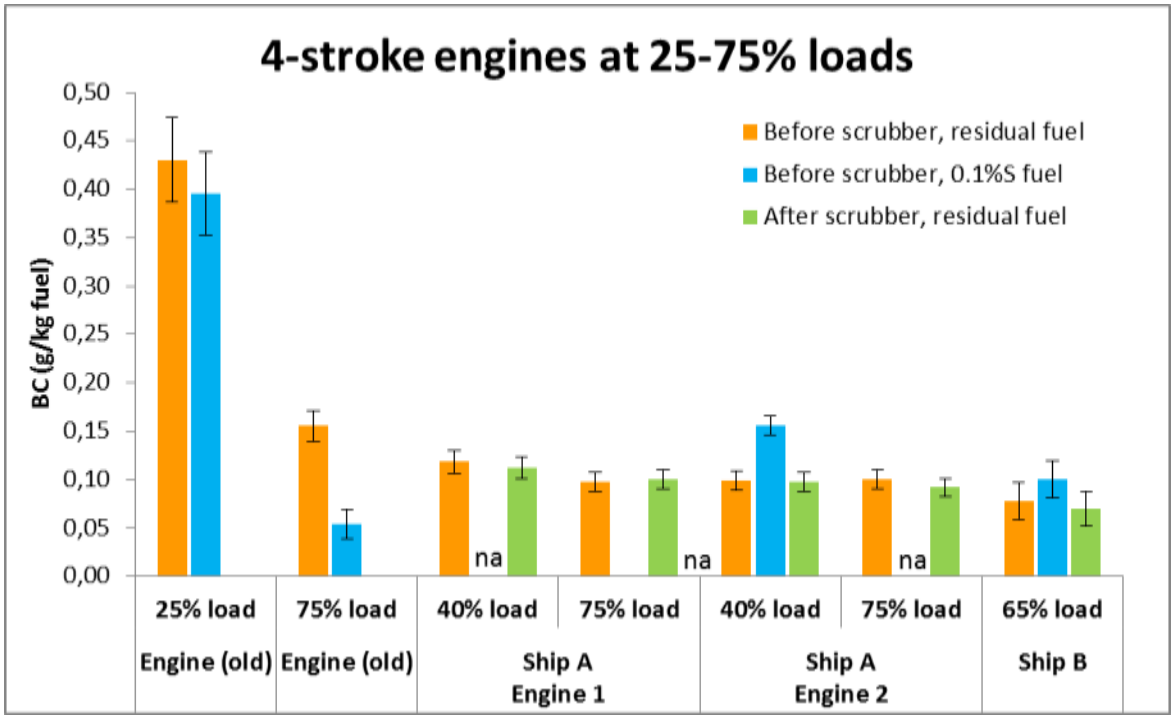

Figure 1. Engine (Old) represents the results of BC emission measurements for a laboratory engine equipped with a mechanical injection system. Ship A is a cruise ship and ship B is a RoPax ship equipped with modern electrically controlled diesel engines. The average BC emissions are shown in the figure. Standard deviation for the measured BC emissions is estimated as ±10% for an old engine and ship A, and as ±25% for the preliminary results with ship B (shown as error bars). For an old engine at 25% load n=8 for 2.5%S fuel and n=21for 0.1%S fuel. At 75% load n=8 for 2.5%S fuel and n=16 for 0.1%S fuel. For Ship A, engine 1 at 75% engine load, n=12 after scrubber and n=14 before scrubber. At 40% load, n=13 after scrubber and n=2 before scrubber. For engine 2 at 75% load, n=23 after scrubber and n=24 before scrubber. At 40% load, n=19 after scrubber and n=14 before scrubber. For MGO, n=13. Preliminary results for Ship B: at 65% engine load, n=6 before scrubber, n=9 after scrubber and n=3 for MGO before scrubber.

Conclusions on the BC emission measurements for 4-stroke diesel engines

9 The average BC emissions from the four 4-stroke marine engines were low (from 0.09 to 0.16 g/kg fuel) at engine loads ranging from 40% to 75% using residual fuels.

10 Switching from residual to distillate fuel in modern electrically controlled diesel engines did not reduce the average BC emissions in the onboard measurements at engine

loads from 40% to 75%. However, for an old mechanically controlled laboratory engine a significant reduction in the average BC emissions was observed, when residual fuel was changed to distillate fuel at 75% engine load.

11 Scrubber did not significantly affect the average BC emissions, or the average BC emissions reduced slightly. However, in addition to reducing the SO_X emissions, scrubber did also significantly reduce PM and PAH emissions.

Action requested of the Sub-Committee

12 The Committee is requested to note the outcome of the BC emission measurements for 4-stroke diesel engines and to decide as appropriate.

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References

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