Ministry of Environment
of Denmark
Environmental
Protection Agency

Airborne Monitoring of Sulphur Emissions from Ships in Danish Waters

2020 Campaign Results

Environmental Project
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Sources must be acknowledged.

Contents

Acronyms / Definitions

2017 Campaign	DEPA 2017 Airborne Sulphur Monitoring Campaign
2018 Campaign	DEPA 2018 Airborne Sulphur Monitoring Campaign
2019 Campaign	DEPA 2019 Airborne Sulphur Monitoring Campaign
2020 Campaign	DEPA 2020 Airborne Sulphur Monitoring Campaign
AIS	Automatic Identification System
ANNEX VI	MARPOL Annex VI for the Prevention of Air Pollution from Ships
DEPA	Danish Environmental Protection Agency
EMSS	Explicit Mini Sniffer System
FSC	Fuel Sulphur Content
MARPOL	International Convention for the Prevention of Pollution from Ships
RSD	Relative Standard Deviation
SECA	Sulphur Emission Control Area

Summary

This report presents the results of the airborne activities to monitor ship sulphur emissions in Danish waters conducted during 2020 by Explicit ApS on behalf by the Danish Environmental Protection Agency (DEPA). The activity is part of the Danish Government's programme to enforce the sulphur rules under MARPOL Annex VI.

This year's activities focused on the deployment of the manned helicopters for broader surveillance of maritime emissions using the Explicit Mini Sniffer System.

The main findings of the 2020 report can be summarized as follows:

- Of the 602 ships measured during the period January-November 2020, only 12 ships (2 %) were found to have substantially elevated fuel sulphur content levels at or above 0.15 %.
- This level is the lowest recorded in the past four years, and a notable decrease from 2019 (3.6 %). As such, the pattern in Danish waters follows the general trend observed throughout the Northern European SECA of steadily improving sulphur compliance.
- Adding to the decreasing effect has been the introduction of the global cap which appears to have had a positive spill-over effect inside the SECA as well. Only one vessel was observed with emissions indicating 0.5 % FSC, with no observations made above the global cap threshold.
- At the lowest end of the spectrum, scrubbers continue to positively impact general emission levels, however, with the noted exception from 2019 – where scrubbers started making their intro into Danish waters – that ships appear to now be optimizing their abatement operations more, possibly to save on energy and costs.
- As in 2019, non-compliance was found to be concentrated North of the Great Belt and Øresund bridges in Kattegat and Skagerrak but with no apparent directional patterns.
- Due to the national lockdown caused by the corona pandemic, operations where temporarily halted in the months of April and May. However, an early start to the surveillance season and an intensive period in June and July meant, the lockdown had no impact on the annual target number of measurements.

Ships by now are aware of the regular airborne sulphur surveillance effort in Danish waters and appear to be adapting their behaviour accordingly, underlining the preventive value of the programme.

1. Operations

As in previous years, the 2020 Campaign was conducted using manned helicopter operations to survey a broad section of Danish waters. Due to the pandemic, surveillance was temporarily halted in the months of April and May.

All sulphur deployments in 2020 where conducted by Explicit ApS in collaboration with Charlie 9 Helicopters ApS as part of the Danish Government's programme to enforce the sulphur rules under MARPOL Annex VI.

1.1 Measurement methodology and technology

No changes were made to the sensor technology or analysis methodology compared to the setup used in previous years. Reference is made to the 2017 Campaign report for details on the measurement methodology, instrumentation, and operational setup.

1.2 Aircraft platforms

All operations in 2020 were carried out using either an Airbus AS355NP twin-engine helicopter or an Airbus H125 single-engine helicopter. No other aircraft platforms were used.

As in previous years, the helicopter was equipped with the Explicit Mini Sniffer System in a dual configuration, i.e. with two parallel sensor instruments operated in tandem. For more on the application of multiple parallel sampling, please see the 2017 Campaign report.

1.3 Operations

Unlike in past years, where weather conditions have prevented surveillance in the winter and late autumn, this year's operations managed to cover the full period from January through November.

Because of the national lockdown caused by the corona pandemic and the impact on port state control operations, surveillance was temporarily halted in the months of April and May. Instead, operations intensified in the months of June and July.

The distribution of measurements over the full campaign period as well as by hour on the day is presented in Figure 2 and 3 respectively.

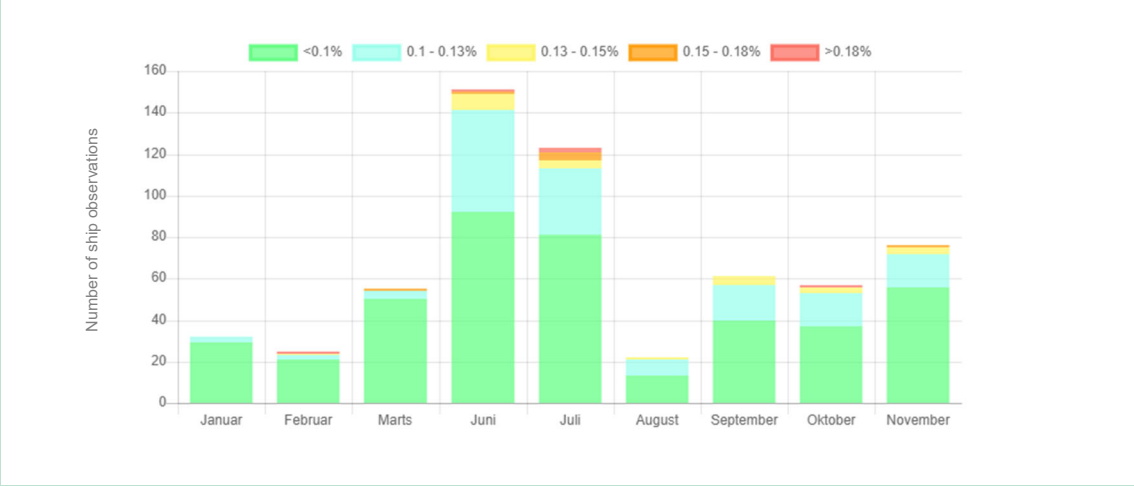

FIGURE 2. Distribution of measurements by campaign month. Note, the colours indicate FSC levels. For further see 2.2.

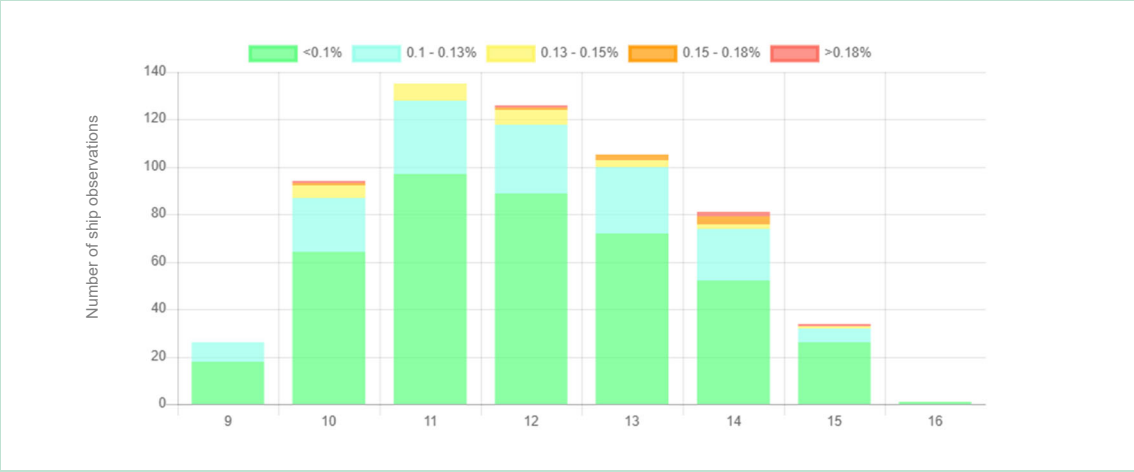

FIGURE 3. Distribution of measurements by hour interval. Note, the colours indicate FSC levels. For further see 2.2.

1.4 Other observations

All operations were carried out in according with DEPA instructions. No technical issues were experienced during missions.

As in previous years, the ships appear to be increasingly aware of the regular airborne surveillance of ship emissions in Danish waters, underlining the preventive effect of the programme.

On one occasion this year this impact was demonstrated as a vessel, in Route Tango heading North, on approach by the aircraft appeared to turn on its scrubber before sampling could take place.

On a separate occasion a vessel with multiple exhaust funnels where found to have compliant emissions from one stack, while the other had clear traces of elevated sulphur levels.

The team also occasionally observe vessels with distinct visual changes in their emissions as the helicopter nears, indicating a change in engine operations and/or abatement methods. However, these changes do not necessarily indicate non-compliance.

602

ship observations were collected and analyzed for sulphur compliance in 2020.

2. 2020 Campaign Results

2020 saw a notable reduction in the sulphur emissions from ships in Danish waters compared to previous years, both in terms of the percentage of non-compliance but also by the absence of gross violations. In particular, the introduction of the 0.5 FSC % 'global cap' appears to be having a positive spill-over effect inside the ECA.

2.1 Dataset

The full dataset for the 2020 Campaign consists of 602 independent ship observations. Due to their frequent operation in Danish waters, some vessels were measured multiple times during the year, however at a maximum on four occasions.

Ships were observed throughout Danish waters with an emphasis on the international shipping lanes and areas with the highest maritime traffic density. Except for 5 anchored vessels, all ships were observed while underway. The map in Figure 1 depicts the location of all measurements including vessel headings and corresponding FSC levels.

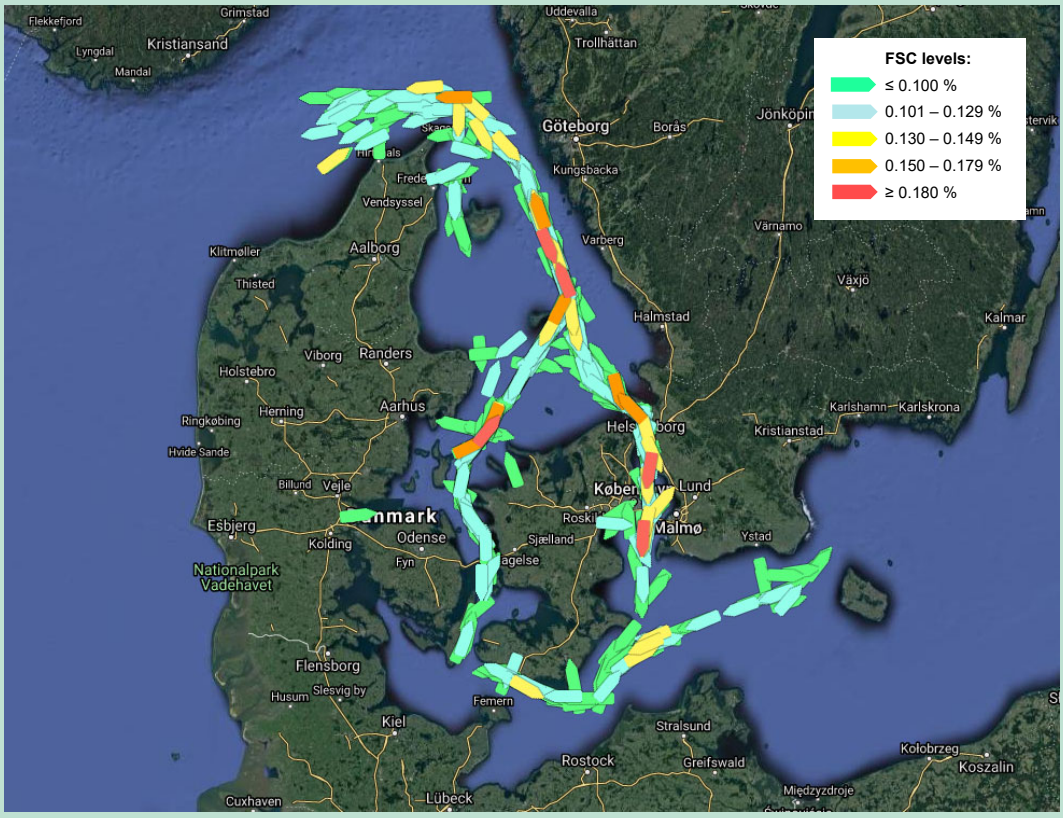

FIGURE 1. Geographical map of all measurements.

More ships are opting for scrubbers
More ships are being equipped with exhaust gas cleaning systems also known as scrubbers to rinse-out excess sulphur from the emissions. The emissions from a scrubber vessel are often distinctive by their white exhaust plumes caused by water vapor being released during operation. Many scrubbers remove more sulphur than the law requires, resulting in emissions levels below the legal 0.10 % limit. This effect is evidenced in the emissions data.

All ships were identified based on their AIS signals collected directly from the vessels during flight. No third-party sources have been used to establish ship ID. A breakdown of the dataset according to primary vessel type, based on the AIS data, is presented in Table 1.

TABLE 1. Distribution of measurements by vessel type

Type	Cargo	Tanker	Passenger	Other	Not available	Total
Measurements	391	158	31	14	8	602
% of total	65.0	26.2 %	5.1 %	2.3 %	1.3 %	100 %

2.1.1 Measurement quality

Of the 602 ship observations, 554 measurements (92 %) were classified as high quality (≥ 6.00 in quality score) according to the systemic quality scoring protocol, meaning the operational team was able to successfully optimize the sampling position in the plume to satisfy all sensor requirements.

A breakdown of the quality scores is presented in Table 2. The methodology for the quality scoring protocol is described in detail in the 2017 Campaign report.

TABLE 2. Distribution by quality scores

Quality score	Low (0-3)	Medium (3-6)	High (>6)	Total
Measurements	13	35	554	602
% of total	2.2 %	5.8 %	92.0 %	100 %

2.2 Observed FSC levels

The measurement distribution by FSC level is presented in Figure 4. When analysing the distribution of the measurements on different FSC levels, the 2020 data corresponds to the pattern observed in previous years with an approximate normal distribution peaking in and around the 0.10 % regulatory threshold applicable within the SECA.

This year's overall distribution profile shows a median FSC value of 0.084 % with a peak value at 0.106 % FSC. This result is in line with the previous reported levels and goes to confirm that the data shows no immediate bias.

Two things are particularly noticeable in this year's dataset.

First, the absence of any measurements above the 0.5 % global cap threshold and the general low level of non-compliant observations (only 2 % at or above 0.15 % FSC) is noteworthy. At the introduction of the global cap in January 2020, some voiced concern that the reduced split between legal limits outside and inside the SECA might cause some ships to ignore the change-over rules and simply opt for 0.5 % fuel only. This year's emissions data shows this is not the case. Vessels continue to comply with the stricter emissions limits inside the SECA with only one reported case at the approximate 0.5 % FSC global limit.

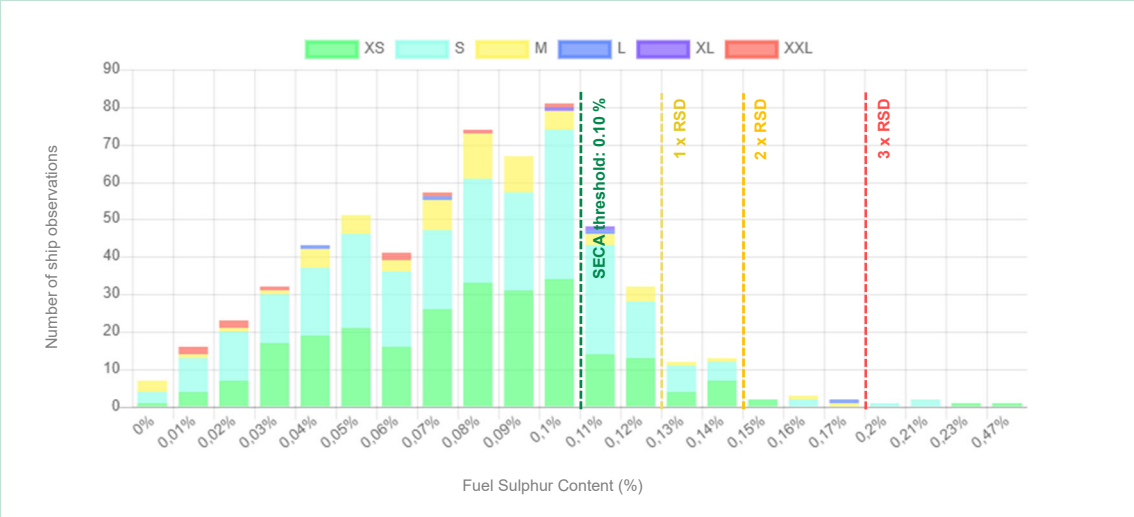

FIGURE 4. Distribution of measurements by measured FSC. Note: The colours indicate difference in vessel sizes according to their length[1]. The dotted lines indicate the various compliance cut-off levels for 1xRSD, 2xRSD and 3xRSD respectively.

[1] XS = <130m, S = 130-220m, M = 220-290m, L = 290-300m, XL = 300-366m, XXL = >366m.

In fact, the global cap appears to be having a positive spill-over effect inside the SECA in the form of fewer cases of contaminated emissions from fuel changeovers.

SO_2 is a highly reactive gas meaning it will 'stick' to most surface materials it comes into contact with. This phenomenon sometimes causes the sulphur in exhaust gasses to build up in the funnel system and be released delayed leading to residual trails of elevated sulphur in the emissions. With the introduction of the global cap, and a smaller difference in permitted sulphur levels inside and outside the SECA, this impact appears to have diminished which could also explain why we've seen a further improvement in sulphur compliance this year. The flip side of this development is that late fuel changeovers (ships that wait until well inside the SECA before changing to ultra-low sulphur fuels) have become even harder to detect in Danish waters.

Second, the composition of data below the 0.10 % FSC limit has changed. Where the 2019 data showed a distinctive 'scrubber peak' at the 0.01 % level, this peak is no longer observable. Whether the change is caused by a tuning of the scrubbers to save on energy consumption or some other parameter is unknown.

Overall, the number of observations at or below the SECA 0.10 % FSC threshold is on par with 2019, with approximately 70 % of all observations recorded in this range (= green ships on the map). In general, the observed emissions patterns are consistent with other remote monitoring findings reported by other similar campaigns in Europe and thus not specific to this dataset.

A breakdown of the distribution is presented below. Where relevant, the data is compared to the results of the 2017, 2018 and/or 2019 Campaigns.

2.2.1 Distribution of FSC values by cut-off level

As shown in Figure 4, the threshold at which a measurement can be deemed to breach the regulator compliance threshold of 0.10 % FSC depends on the RSD uncertainty applied to the measurement. The higher the RSD applied, the stronger the probability that the measurement is in fact above the SECA threshold. In Table 3, all measurements are grouped according to their RSD level.

TABLE 3. FSC distribution by level of uncertainty

FSC	RSD	Colour	Measurements	% of total
≤ 0.100 %	N/A		419	69.6 %
0.101 – 0.129 %	N/A		147	24.4 %
0.130 – 0.149 %	1 x RSD		24	4.0 %
0.150 – 0.179 %	2 x RSD		7	1.2 %
≥ 0.180 %	3 x RSD		5	0.8 %
Total			**602**	**100 %**

At the 95 % coefficient level (2xRSD) – the recommended level used when interpreting fuel analysis results according to ISO 4259 – the number of vessels measured with elevated FSCs

LNG vessels are on the rise
With the need to find alternative fuels to reduce sulphur and CO_2 emissions, an increasing number of ships are opting for liquified natural gas (LNG), leading to more observations of LNG vessels in Danish waters. This increase is expected to continue in the coming years.

indicating non-compliant fuel was 12 or 2.0 % of the total. This is a decrease from last year where 3.6 % of all observations were found to be ≥ 0.15 % FSC and a significant improvement from 2018 where 7.3 % of all vessels were found to be non-compliant.

This year, only 0.8 % of all vessels were observed ≥ 0.18 % FSC compared to 2.1 % in 2019. With the exception of 2018, the data thus shows a steady year-on-year improvement in sulphur emissions levels in Danish waters.

A year-on-year comparison of the FSC values ≥ 0.15 % is shown in Figure 5.

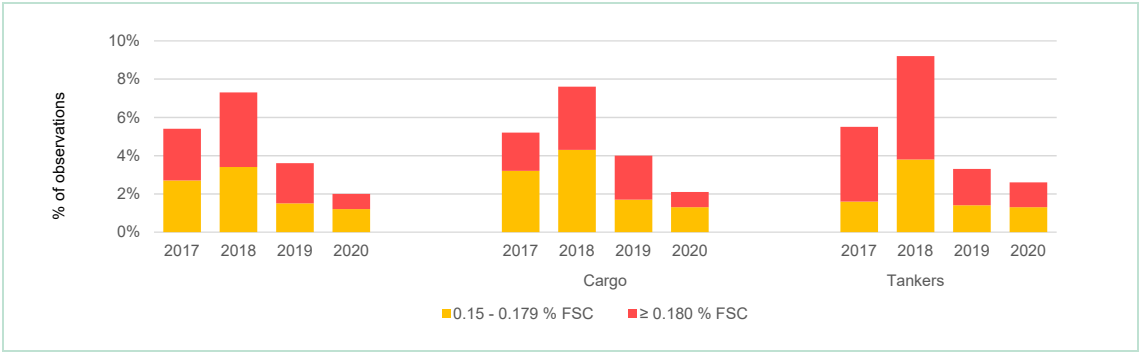

FIGURE 5. Observations with FSC values at or above 0.15 % FSC as a percentage share of the total number of measurements in a group (all, cargo or tankers).

2.2.2 Distribution of FSC values by vessel type

In table 4, the FSC distribution is broken down by vessel type focusing only on cargo and tanker ships. These represent more than 91 % of the total dataset and thus make up the bulk of the data. The remaining 52 observations are made up of passenger ships and miscellaneous other types.

TABLE 4. FSC distribution by vessel type and level of uncertainty

FSC	RSD	Colour	Cargo		Tanker	
			No.	% of total	No.	% of total
≤ 0.100 %	N/A		271	69.3 %	103	64.8 %
0.101 – 0.129 %	N/A		97	24.8 %	43	27.0 %
0.130 – 0.149 %	1 x RSD		15	3.8 %	9	5.7 %
0.150 – 0.179 %	2 x RSD		5	1.3 %	2	1.3 %
≥ 0.180 %	3 x RSD		3	0.8 %	2	1.3 %
Total			**391**	**100 %**	**159**	**100 %**

The improvement in compliance is most apparent in cargo ships, where cases of non-compliance have dropped from 4 % to 2.1 %. For tankers, the improvement is less significant with a recorded reduction in non-compliance from 3.3 % in 2019 to 2.6 % in 2020.

For all other types, no non-compliance was observed with the highest emissions value recorded at 0.129 % FSC.

2.2.3 Distribution of FSC values by geographical location

All cases of non-compliance this year – except for one single observation – were found North of the Great Belt and Øresund bridges, as illustrated on the map in Figure 1. This year thus repeats the pattern from 2019 that found a higher risk of non-compliance in Northern waters.

The cause behind this North/South geographical difference is unknown.

Similarly with last year, no clear directional patterns were observed. Non-compliance is found just as frequently with vessels heading outbound towards the North Sea as inbound from the North Sea or with vessels operating within the surveyed area.

2.3 Other observations

No other observations were made. For details on the operations, please see chapter 1.

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