Summary of the project report: Low Sulphur Fuel Oils – identification of key environmental impacts in a cold marine environment

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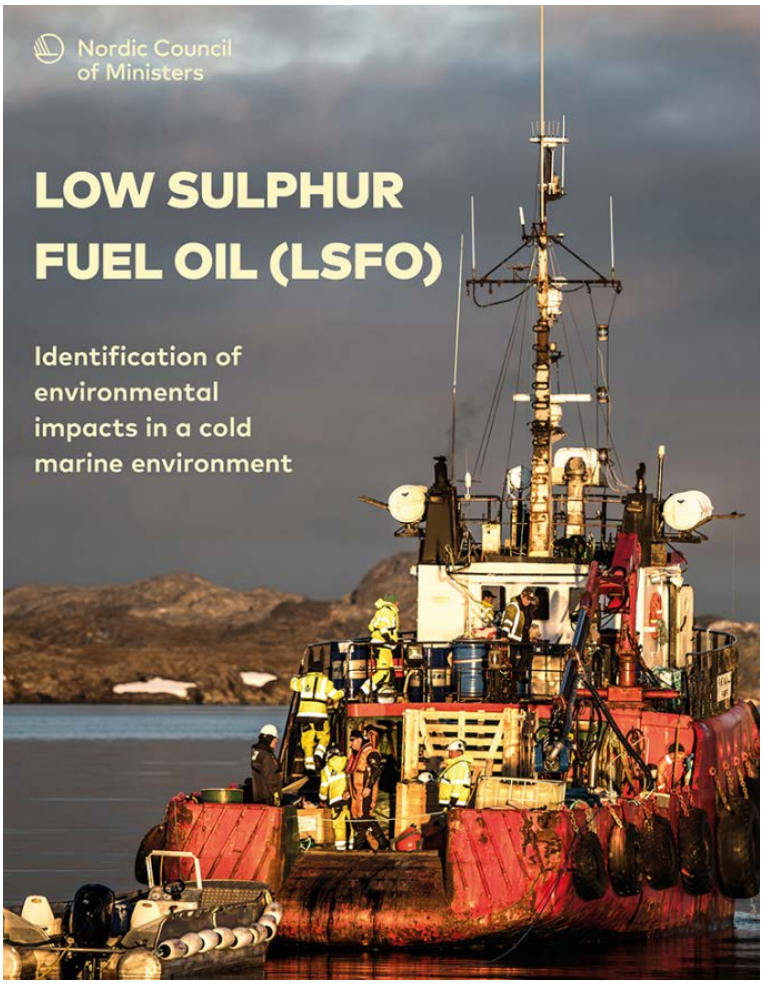

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Data sheet

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Title: Summary of the project report: Low Sulphur Fuel Oils – identification of key environmental impacts in a cold marine environment

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Background

This note provides an extended summary of the project 'Low Sulphur Fuel Oils – identification of key environmental impacts in a cold marine environment'. The project was funded by the Nordic Council of Ministers – The Marine Group and conducted in the period from 2021-2022. The project was a collaboration between the Danish Centre for Environment and Energy, Aarhus University, Denmark, SYKE, Marine Research Centre Finnish Environment Institute, Finland and the Norwegian Coastal Administration, Norway. The final project report (Fritt-Rasmussen et al. 2023. Low Sulphur Fuel Oil (LSFO): Identification of environmental impacts in a cold marine environment. 10.6027/temanord2022-558) can be found on the web.

The purpose of the project was to investigate the mitigation possibilities of low sulphur fuel oil (LSFO) spills in a cold environment. The project included small-scale laboratory experiments to investigate the effectiveness of combating LSFO spills in cold seawater by in-situ burning and chemical dispersion, respectively. In addition, the fate and biodegradation of LSFO as well as chemically dispersed LSFO in a cold environment was studied. The overall purpose was to evaluate which key organisms are at most risk in the marine environment from a LSFO spill when mitigated by in situ burning or chemical dispersant.

Low Sulphur fuel oil types

Three different LSFOs were included in the small-scale laboratory experiments: wide range diesel (WRD), ultra-low sulphur fuel oil (ULSFO 2018) and heavy distillate marine ECA 50 (HDEM50). The study only includes fresh oils and not weathered (i.e. evaporated and emulsified) oils. Oil weathering will further reduce the potential for oil spill combatting.

WRD is a heavier diesel fraction, considered to be a distillate fuel. This oil was also included in studies by Øksenvåg et al. (2021) with the internal SINTEF ID 2021-361-S2 FRESH (WRG/MSD). ULSFO 2018 is a residual fuel oil with a high density, pour point and wax content. This oil was also included in studies by Sørheim et al. (2020) with the internal SINTEF ID: 2019-11170. HDME50 is considered as a distillate fuel oil made from heavy distillation cut with minor content of heavy compounds such as asphaltenes (Sørheim et al. 2020). This oil was also included in studies by Hellstrøm (2017), Hellstrøm et al. (2017) and Faksness and Altin (2017), with the internal SINTEF ID: 2016-0231. Additionally, the project also included a heavy fuel oil (IFO 180) and an arctic diesel type oil (AGO).

Small-scale dispersion tests

Small-scale laboratory dispersant tests were conducted at 2 °C and 5 °C for the two LSFOs WRD and HDME50. Different methods exist for testing dispersion effectiveness, and generally, it is assessed that small-scale test methods underestimate the dispersion effectiveness compared to large-scale test facilities and this should be kept in mind when analysing the results of the present study. The chemical dispersant used in the dispersion tests was Finasol OSR 52. Saltwater with a salinity of 30.3‰ was used in the experiments. The tested dispersant:oil ratios (DOR) were 1:10 and 1:25. However, for the HDME50, 2°C experiments, successive dispersion (2 x 1:10) were included.

The oil dispersed in the seawater was extracted with dichloromethane (DCM), and the oil content was assessed using a fluorescence spectrophotometer. The PAH (polyaromatic hydrocarbon) concentration in the extract was measured in some of the samples by GC-MS.

Based on the small-scale dispersion tests with non-weathered LSFOs, we saw that one of the oils tested, the WRD, was somewhat dispersible whereas another oil, the HDME50, was poorly dispersible even for successive dispersant applications. The tests were conducted at 2 and 5 °C, and increasing the temperature did result in an enhanced dispersibility, but it was still very low at 5 °C. The oils tested had a high pour point, which is considered to be the main reason for the low dispersibility. When such oils are spilt at sea in the Arctic, or other cold waters, the oil will solidify. Weathering will also change the oil properties resulting in an oil that in some cases could be even more difficult to disperse. The results suggest that chemical dispersion is not an effective method to combat low sulphur fuel oils spills at cold sea surfaces. Higher mixing energy, higher temperatures and successive applications somewhat improves the dispersibility. Still, it is assessed, that low sulphur fuel oils will mainly be a risk for organisms associated to the sea surface and the shoreline if the oil is beaching.

The measurements of the PAHs in the extracts from the dispersion tests showed that the PAH composition in water was similar to the PAH composition in fresh oil. This suggests that the PAHs found in the water were mainly a result of dispersion and only to a minor degree dissolution. The PAHs in the water samples were dominated by naphthalenes and phenanthrenes.

Summary from Fritt-Rasmussen et al. (2023):

Based on the small-scale dispersion tests on non-weathered LSFOs, WRD and HDME50, it was found that:

- *WRD was somewhat dispersible (up to an average of DE 50%), the highest values being found for DOR 1:10 and at 5 °C.*
- *HDME50 was poorly dispersible even in the case of successive dispersant applications.*
- *Increasing the test temperature from 2 to 5 °C had a positive impact on the dispersion effectiveness. For WRD DOR 1:10, the effectiveness increased from < 20% to > 50% dispersion effectiveness.*
- *The concentration of PAHs dispersed in the water was associated with dispersion effectiveness. The PAHs were dominated by the naphthalenes and phenanthrenes, the PAHs with the highest water solubility, but also by the dominant PAH components in the fresh oil (Figure 7).*

Small-scale burn tests

Burn efficiency, mass burning rate/regressions rate and possible sinking of burn residue were determined from small-scale in-situ burning tests for two LSFOs – WRD and ULSFO. The burn tests were completed on seawater (30.3 psu) in Pyrex glass containers (diameter = 19 cm), placed in a water bath (100 cm x 100 cm and 20 cm high) in open air, and with low winds. 200-500 g of oil were burned, corresponding to 10 mm and 20 mm oil film thickness, respectively. The oil was ignited by a butane torch up to 3 times of 10 s, if necessary. The possible sinking of the residue was examined after flame out. The weight of the oil before the burn and the weight of the residue after the burn were measured on a scale.

From the small-scale burn tests, we found that all the oils ignited and burned after one or two ignition attempts. The resulting burning efficiencies were all above 50 %. The oils tested were fresh and water-free LSFOs, but in the sea the oil will weather and after a short while change its properties resulting in an oil that are more difficult to ignite, primarily due to uptake of water and evaporation of volatile compounds and the window of opportunity for burning could be short. The burn residues were kept on the water surface for investigation of the potential sinking after cooling to ambient temperatures and showed that none of the burn residues sank. Therefore, the potential environmental impacts from a successful burn of the tested LSFOs are expected to be associated to the smoke plume and remaining residue in the environmental compartments such as the sea surface and/or if residue reaches shorelines and thus to organisms associated to sea surface and the intertidal zone.

Summary from Fritt-Rasmussen et al. (2023):

Based on the small-scale burn tests with two different non-weathered LSFOs, WRD and ULSFO 2018, it was found that:

- *All of the oils were ignitable. However, ULSFO 2018 was the most difficult to ignite.*
- *The burn efficiencies for WRD were up to 85% and for ULSFO 2018 74%. The regressions rates were 0.92 mm/min and 0.6 mm/min for WRD and ULSFO 2018, respectively.*
- *None of the burn residues sank after cooling to ambient temperatures.*
- *There was an increase in the 4-6-ring PAHs in all residues, most likely due to pyrogenic production.*

Microcosm biodegradation experiments

Microcosm experiments were conducted to determine biodegradation of LSFO oils in cold marine environments. The LSFOs tested included WRD and ULSFO. In addition, the effect of dispersant Finasol 52 on the biodegradation rate was investigated when applied together with the WRD oil.

Microcosms experiments were 1 liter glass bottles filled with seawater collected from coastal or open sea location of Gulf of Finland. Equal amounts of each crude oil were immobilized on absorbent fabric and transferred to glass bottles. For dispersant treatments, dispersant and oil were mixed and transferred directly to glass bottles and the bottles were incubated at 5°C for four weeks. Chemical analyses were performed in the beginning of the experiment, after two-week incubation and at the end of the experiments.

Overall, the results indicated that LSFOs biodegraded slowly in the cold temperature but both WDR and ULFSO did degrade during 28d test period, 17% and 46% respectively. The results showed that the lighter fractions, C10–C20, decreased more than the heavier fractions, C20–C40, for both oils. Sterile control treatments showed low abiotic degradation of the oils during the experiment. For the experiments where dispersants were added, the results indicated that the biodegradation did not increase, however interpreting the results is difficult as there were some uncertainties with the efficiency of the extraction in the presence of dispersant (Tonteri et al. 2023) in the chemical analysis method.

Summary from Fritt-Rasmussen et al. (2023):

Based on the biodegradation tests of WRD and ULSFO 2018, it was found that:

- *ULSFO 2018 and WRD had degraded 46% and 17% after 28 days.*
- *An improved method for adding high pour point oils was tested.*
- *Dispersant addition did not increase biodegradation.*
- *Dispersant addition inhibited biodegradation, possibly due to toxic effects on microbes.*

Concluding remarks

Assessing which organisms that might be most at risk conclude, based on the oils tested in this small study, that there is a low risk of bacteria, plankton, fish, fish larvae/fry and other pelagic organisms to be exposed to oil or chemically dispersed oil. However, there is a wide variation in the pour point and also the viscosity of the LSFOs, where some of these may have potential for dispersant use. As the results further suggest that fresh LSFOs as well as burn residues are persistent on the seawater surface, we assessed that the risk for the oil to reach the seabed is minor. But, the density of the burn residues and weathered oil could increase, also because of sediment building-in, and this would particularly be of concern in shallow waters, where the oil may reach the seabed and potentially impact the benthic community. For oil at the sea surface, the most vulnerable organisms are seabirds. As the oils tested in this study indicate a high degree of persistence on the sea surface, the risk of oil and burn residue beaching and possible smothering of the shoreline community is evident. Further, this can cause toxic effects to fish species spawning near shoreline in coastal areas. The biodegradation rates are comparable to or slightly lower than degradation rates earlier reported for heavy fuel oil at low temperatures (Fritt-Rasmussen et al. 2018), which means that the natural degradation after a LSFO spill could be slower than regular HFO.

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