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WEATHERING BEHAVIOUR AND OIL SPILL RESPONSE OPTIONS FOR "NEW GENERATION" OF LOW SULPHUR MARINE FUEL OILS (LSFO)

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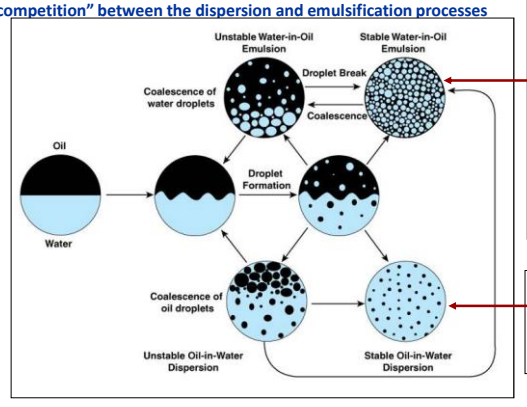
Mixing of oil and water at sea

The "competition" between the dispersion and emulsification processes



Incidents:

Heavy Bunker Fuel Oils (HFO, e.g. IFO-180 / IFO-380:
***"Volgoneft"* (Sweden -1990)**
***"Baltic Carrier"* (Den. - 2001)**
***"Fu Shan Hai"* (Den. - 2003)**
***"Rocknes"* (Norway - 2004)**
***"Server"* (Norway - 2007)**
***"Full City"* (Norway - 2009)**
***"Godafoss"* (Norway -2011)**

VHFO (IFO-500):
***"Prestige"* (Spain, 2003)**

Light Distillates e.g:
***"North Cape"* (RI, 1996)**

***"Helge Ingstad"* DMA / MGO (Norway - 2018)**

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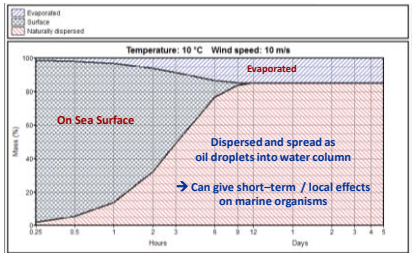
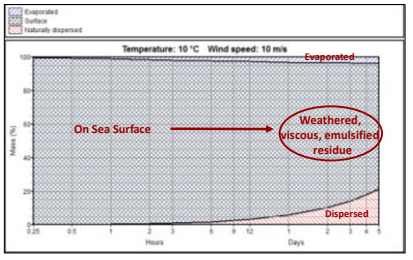
Example of fate of marine fuels at Sea (mass balances)

Predictions by SINTEF Oil Weathering Model (OMW)
Sea temperature: 10 °C, Wind condition: 10 m/s (breaking waves)

Marine Gas Oil (DMA distillate):



Heavy Fuel Oil (HFO, e.g. IFO-180 NS):



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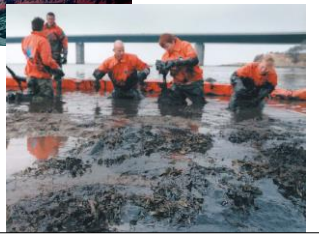
Examples from Heavy Fuel Oil incidents

Collision: "Baltic Carrier" / "Tern", Denmark (2001)



"Rocknes" incident, Norway (2004)

Key question: How will the "new generation" of LSFO behave at sea ?

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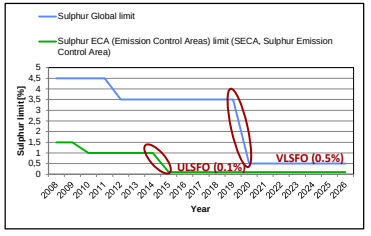
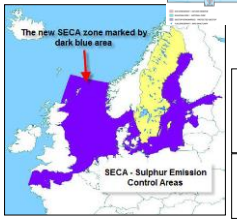
Background(s)

SECA – Sulphur Emission Control Areas

Marpol Conventions / IMO Regulations





Spitsbergen / Svalbard islands in the Barents Sea

SECA: North Sea, Baltic, Not Norwegian sea / Arctic

SECA: North America (East/ west coast)

1. New generation fuel oils ("Hybrid Fuels") are replacing the traditional Heavy bunker fuels, HFOs (e.g. IFO- 180 and IFO 380) for use in the SECA-area (< 0.1%S) and global (< 0.5%S)
2. For Norway: Svalbard / Spitsbergen: Not allowed to carry HFO (only DMA – Diesel)

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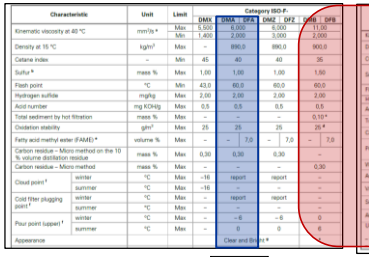
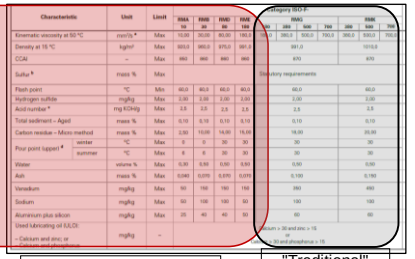
ISO 8217 Fuel Standards (2017)

Requirements for Marine Distillate Fuels:



Requirements for Marine Residual Fuels:



MGO = DMA

"New generation LSFO (Hybride fuels):
- ULSFO: < 0.1 % S
- VLSFO: < 0.5 % S

Wide spectre. Do not fit into one specific grade

"Traditional" HFOs: (IFO-180 /380)

VHFOs: IFO-500 /700

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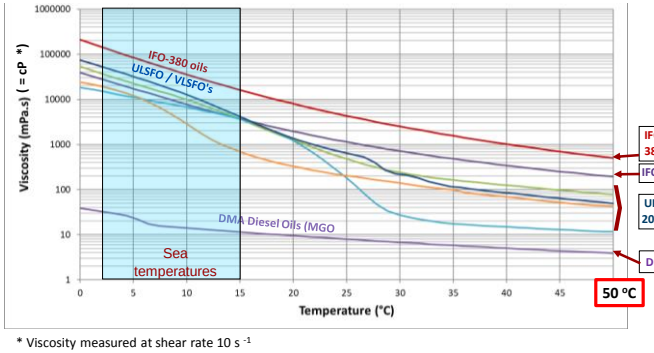
Viscosity of different marine fuels (non-weathered) versus temperature (temp-sweep)



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* Viscosity measured at shear rate 10 s^{-1}

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Objectives – laboratory / basin studies

Project initiated by the Norwegian Coastal Administration (NCA): 2016 – 2017

- Get a better documentation of the weathering properties, toxicity, fate and behaviour of todays marine fuel oils when spilled at sea (Both North Sea and Arctic water temperatures)
  → With relevance for the effectiveness of different oil spill response options in cold water temperatures
- Weathering behaviour of five gas oils/diesels (DMA-qualities, ref. ISO-Marine distillates) and three "new generation" of Ultra Low Sulphur marine Fuel Oils :
  - Physical-chemical properties (fresh / evaporated)
  - Emulsifying properties
  - Dispersibility (natural and dispersant enhanced)
  - Water accommodated fraction (WAF) and toxicity
  - Ignitability (potential for *in-situ* burning)
  - Skimmer performance testing at NCA basin, Horten

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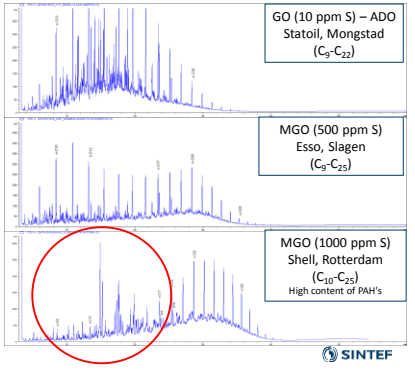
Light refined distillates - Gas Oils / Diesels Oils (all DMA qualities)

- Similar physical properties that result in similar weathering behaviour
  - Poor emulsifying properties
  - High dispersibility (natural and dispersant enhanced)
- Differences in chemical properties result in differences in toxicity
  - High content of aromatic components (PAH's)resulted in higher toxicity for one tested DMA-diesel compared to the other two diesel oils

Gas chromatograms (GC-FID) :



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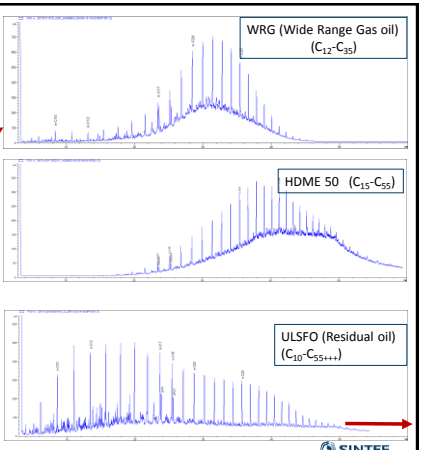
"New generation" of low sulphur marine fuel oils (heavy distillates and residual fuels)

- WRG (Wide Range Gas oil)
- HDME 50 (Heavy Distillate Marine ECA 50)
- ULSFO (Ultra-Low Sulfur Fuel Oil, Shell) Residual oil



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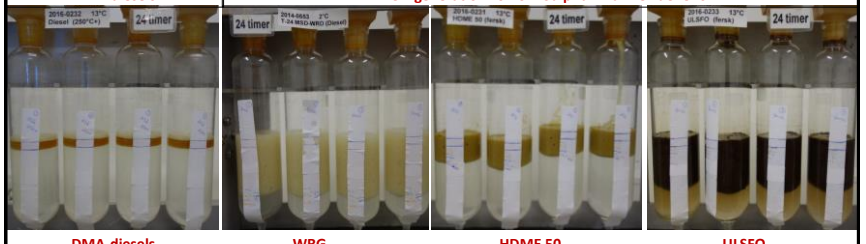
Emulsifying properties

Both at 13°C and 0-2°C, Rotating cylinders – method (Mackay et al., 80's)



DMA-diesels	WRG	HDME 50	ULSFO
(no water uptake)	(→ 85 / 80 % w/o)	(→ 70 / 50 % w/o)	(→ 75 % w/o)
(< 10 mPas)	(→ 500 – 1000 mPas)	(→ 10000 – 20000 mPas)	(→ 15000 – 30000 mPas)

75 % water in oil → increase the volume of oil released by a factor of 4.

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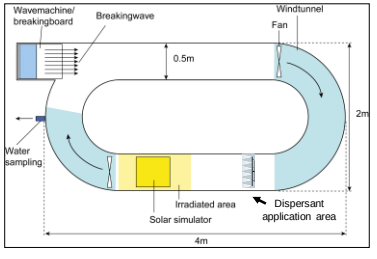
SINTEF's Oil Weathering Flume Basin (meso-scale)

(9 L of oil applied on 5m³ sea water)



Different test conditions:

- Non-breaking waves / breaking wave conditions (→ 16-20 knots wind = 8-10 m/s)
- Typical North Sea / Arctic temperatures (13 and 0-2°C)
- Sunny conditions (sun lamp) / Darkness
- Weathering time for each experiment: 5 days
- Each experiment terminated by application of dispersant (1 – 3x)

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Weathering in meso-scale flume basins

Example Wide Range Gas oil (WRG) at 2°C, (Pour-point = -24°C)

Emulsified over time: → 80 % water, ca. 1000 m Pas, → > 60 % dispersed by Dasic NS and Corexit 9500

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Weathering in meso-scale flume basins

Example ULFSO at 2°C, (pour-point = +24°C)

Just after release (0 hr)
→ immediately solidified lumps
(5000 mPas)

After 72 hours:
Stable emulsion
(75 -80 % water)
(25000 mPas)

After 72 hours weathering, and just after dispersant treatment:

- Low effectiveness: < 20 % disp.
- Surface: 25000 → 14000 m Pas

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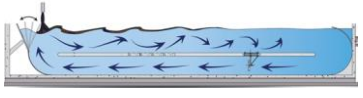
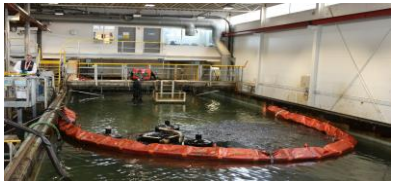
Norwegian National Center for Testing of Oil Spill Response Equipment (NCA, Horten)

- Indoor seawater basin
- Waves and current may be applied



- Length: 30 meters
- Width: 7 meters
- Depth: 4.4 meters
- Water current speed up to 3 - 4 knots
- Wave height up to 0.6 m



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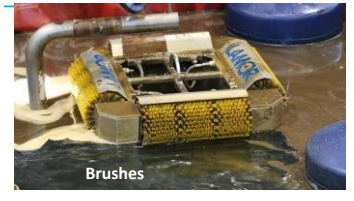
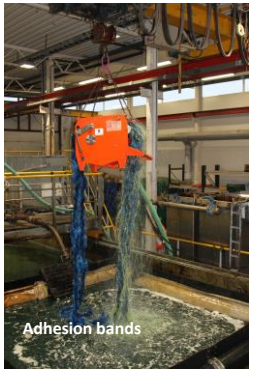
3 different oil skimmer types tested by NCA





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Brush skimmer in HDME 50 (0 °C)

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Brush skimmer in Shell ULSFO (0 °C)

- High pour point (24 °C)
- No inflow of oil towards the skimmers

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Results of adhesion bands in Shell ULSFO

- Necessary to moved the skimmer around
- Very Reduced capacity

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Results of skimmer tests at 0 °C, NCA test basin

Test in seawater temperature 0 °C

	MGO 500 ppm	HDME 50	ULSFO	WRG
Discs				
Brushes				
Adhesion belts				

	Good
	Reduced
	Poor

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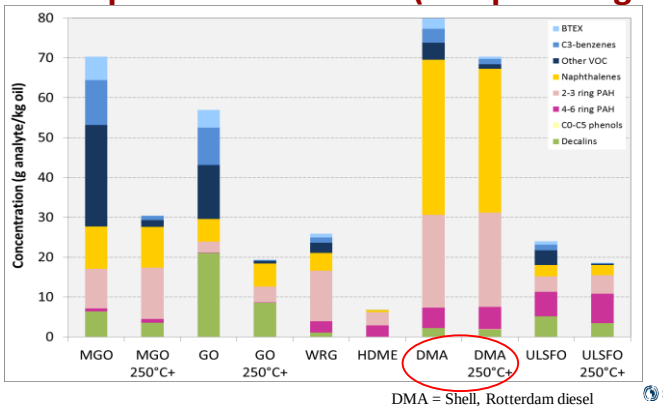
Chemical composition of the oils (component groups)



DMA = Shell, Rotterdam diesel

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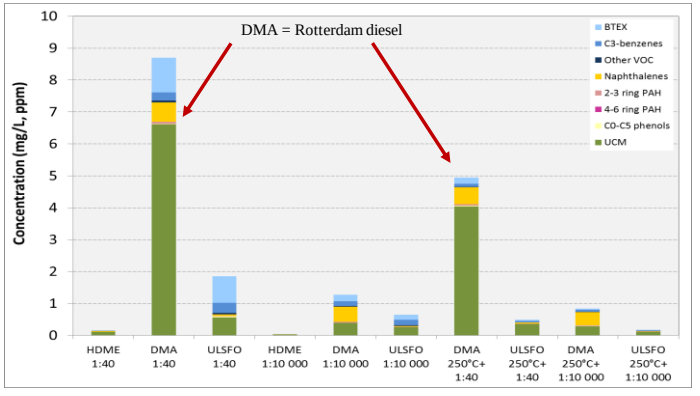
WAF composition (Croserf)



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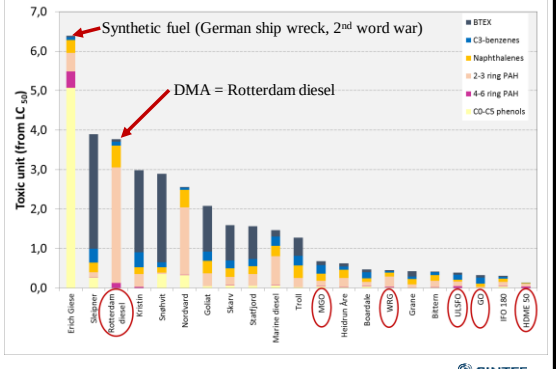
Relative Toxicity of WAFs

- Relative toxicity (EC_{50} and LC_{50} values) of the WAFs tested on:
  - Skeletonema (marine algae)
  - Calanus finmarchicus (copepod)
- Calculation of "Toxic Unit" (TU)



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Ignitability – testing (Potential for ISB)

- Testing performed using SINTEF Burning Cell (bench-scale testing) and mesoscale tray facilities (gelled gasoline)
- All oils ignited in the meso-scale trays conditions, but required long ignition time (up to 20 minutes)
- The flash point of the tested oils spanned from 63 °C to 186 °C

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Summary and further documentation needed

- The tested Diesel oils (all DMA-qualities) expressed similar weathering behaviour, but significantly different in chemical composition and toxicity (WAF)
- The three tested "low sulphur marine fuel oils" showed all significantly different behaviour and weathering properties and highly affected by sea temperature (North Sea vs. Arctic)
- Mechanical recovery and dispersants may have limited effect due to high pour-point values
- *In-situ* burning may have potential – However, long ignition time can be challenging

- **In this study (2016-2017) only three "low Sulphur marine fuel oils" have been investigated**
- **An increasing number of "new generation" of marine fuel oils are now coming on the marked → Importance to follow up with further characterization on these fuel oils**
  → to gain better documentation of the variability in the fate and behaviour when spilled at sea and to document the potential / feasibilities for the different response options

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Follow up projects within LSFO (ongoing and planned):

1): " Characterisation of Low Sulphur Fuel Oils (LSFO)" : 2019 –> April 2020 (0.25 mill EUR)

- Collaboration project between: NCA (Norway), MPRI (Canada), ITOPF and SINTEF
- Additional three "low sulphur marine fuel oils" (both ULSFO and VLSFO) to be characterized and tested

2): EU-project: "IMAROS" (Leaded by NCA): start-up: 2020 – 2021 (0.75 mill EUR)

- EU – part of "Prevention and Preparedness Projects for Civil Protection and Marine Pollution". Cooperation between: Norway, Malta, France, Belgium, Denmark and Sweden
- **I**mproving response capacities and understanding the environmental impacts of a larger number og the new generation low Sulphur **MAR**ine fuel **O**il **S**pills.

Thank you for the attention !

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