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SOMM Forum for framtidas oljevern, 14. September, 2021

"NEW GENERATION" OF LOW SULPHUR MARINE FUEL OILS (LSFO)

interaction studies with shoreline sediments and bedrocks

"Full City" (2009, IFO-180)

"Rocknes" (2004, IFO-380)

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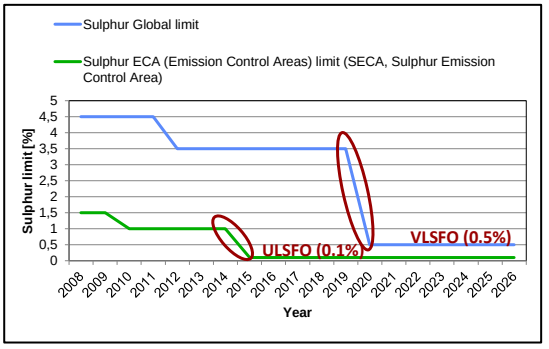
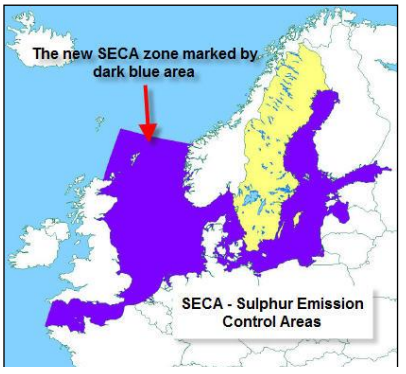
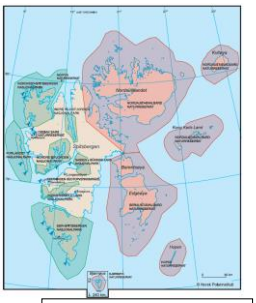
SECA (Sulphur Emission Control Areas) / Global Sulphur Cap

Marpol Conventions / IMO Regulations to reduce SOx – emission to atmosphere







Spitsbergen / Svalbard islands in the Barents Sea

- New generation of Low Sulphur marine Fuel Oils - LSFO (Hybrid fuels): are replacing the traditional Heavy bunker fuels (e.g. IFO 180 and IFO 380) by use of ULSFO in the SECA-areas and VLSFO Globally (2020 Sulphur Cap)
- For Norway: Svalbard / Spitsbergen (2015): Only DMA diesel allowed onboard ships (no heavy distillates of residuals marine fuel oils) in the nature reserves / national parks. From 2022: HFO band for whole Svalbard

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Classification ISO 8217 Fuel Standards (2017)

Requirements for Marine Distillate Fuels

Characteristic		Unit	Limit	Category ISO-F- DMX	DMA	DFA	DMZ	DFZ	DMB	DFB
Kinematic viscosity at 40 °C		mm^2/s [a]	Max	5,500	6,000		6,000		11,00	
			Min	1,400	2,000		3,000		2,000	
Density at 15 °C		kg/m^3	Max	–	890,0		890,0		900,0	
Cetane index		–	Min	45	40		40		35	
Sulfur [b]		mass %	Max	1,00	1,00		1,00		1,50	
Flash point		°C	Min	43,0	60,0		60,0		60,0	
Hydrogen sulfide		mg/kg	Max	2,00	2,00		2,00		2,00	
Acid number		mg KOH/g	Max	0,5	0,5		0,5		0,5	
Total sediment by hot filtration		mass %	Max	–	–		–		0,10 [c]	
Oxidation stability		g/m^3	Max	25	25		25		25 [d]	
Fatty acid methyl ester (FAME) [e]		volume %	Max	–	–	7,0	–	7,0	–	7,0
Carbon residue – Micro method on the 10 % volume distillation residue		mass %	Max	0,30	0,30		0,30		–	
Carbon residue – Micro method		mass %	Max	–	–		–		0,30	
Cloud point [f]	winter	°C	Max	–16	report		report		–	
	summer	°C	Max	–16	–		–		–	
Cold filter plugging point [f]	winter	°C	Max	–	report		report		–	
	summer	°C	Max	–	–		–		–	
Pour point (upper) [f]	winter	°C	Max	–	– 6		– 6		0	
	summer	°C	Max	–	0		0		6	
Appearance					Clear and Bright [g]					

Requirements for Marine Residual Fuels

Characteristic		Unit	Limit	RMA 10	RMB 30	RMD 80	RME 180	Category ISO-F- RMG 180	RMG 380	RMG 500	RMG 700	RMK 380	RMK 500	RMK 700
Kinematic viscosity at 50 °C		mm^2/s [a]	Max	10,00	30,00	80,00	180,0	180,0	380,0	500,0	700,0	380,0	500,0	700,0
Density at 15 °C		kg/m^3	Max	920,0	960,0	975,0	991,0		991,0			1010,0		
CCAI		–	Max	850	860	860	860		870			870		
Sulfur [b]		mass %	Max					Statutory requirements						
Flash point		°C	Min	60,0	60,0	60,0	60,0		60,0			60,0		
Hydrogen sulfide		mg/kg	Max	2,00	2,00	2,00	2,00		2,00			2,00		
Acid number [a]		mg KOH/g	Max	2,5	2,5	2,5	2,5		2,5			2,5		
Total sediment – Aged		mass %	Max	0,10	0,10	0,10	0,10		0,10			0,10		
Carbon residue – Micro method		mass %	Max	2,50	10,00	14,00	15,00		18,00			20,00		
Pour point (upper) [d]	winter	°C	Max	0	0	30	30		30			30		
	summer	°C	Max	6	6	30	30		30			30		
Water		volume %	Max	0,30	0,50	0,50	0,50		0,50			0,50		
Ash		mass %	Max	0,040	0,070	0,070	0,070		0,100			0,150		
Vanadium		mg/kg	Max	50	150	150	150		350			450		
Sodium		mg/kg	Max	50	100	100	50		100			100		
Aluminium plus silicon		mg/kg	Max	25	40	40	50		60			60		
Used lubricating oil (ULO): – Calcium and zinc; or – Calcium and phosphorus		mg/kg	–					Calcium > 30 and zinc > 15 or Calcium > 30 and phosphorus > 15						

ULSDO / ADO (< 10 ppm) (0.001%S)

MGO = DMA

MDO = DMB

"New generation LSFO (Hybrid 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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Four Ultra Low Sulphur Fuel Oils (ULSFO, < 0.1% S) tested

1. MGO 250 °C+ weathered residue (ISO: DMA)
2. WRG (Wide Range Gas oil) (ISO: RMA)
3. HDME 50 (Heavy distillate / residual Fuel) (ISO: RMB)
4. ULSFO (Residual fuel , 80 cSt at 50 deg C) (ISO: RMD)

- Tested on both water-free residues and 50% water in oil (w/o-emulsions)
- Test temperature: 5 °C
- Span in emulsion viscosities: 100 cP → 60,000 cP
- Span in pour-point: < -36 °C → + 24 °C
- Span in wax-content: < 1 % → 21 %

MGO 250°C+ | WRG | HDME 50 | ULSFO-RMD

MGO 250°C+ 50% w/o | WRG 50% w/o | HDME 50 50% w/o | ULSFO-RMD 50% w/o

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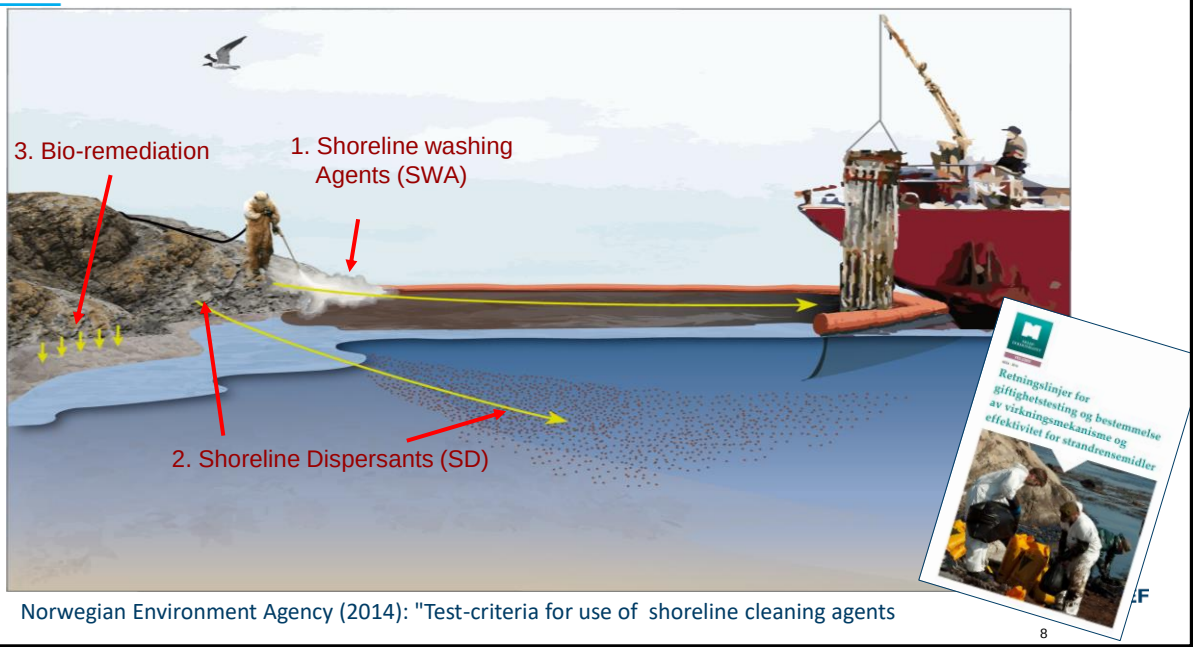
Use of Shoreline Cleaning Agents (SCA) in Norway



Norwegian Environment Agency (2014): "Test-criteria for use of shoreline cleaning agents

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Main objectives with the study

- **To increase the knowledge of fate / behaviour of the different Low Sulphur Fuel Oils (LSFOs / ULSFO) when interacting different shorelines:**
  - Natural washout / remobilization on bedrocks
  - Penetration into sediments
- **Effectiveness of washing / water flushing of bedrocks (immobilized oil)**
  - Temperature: 5 → 45 °C
  - Pressure : 4, 15, 30, 45 bar
  - With and without the use of shoreline washing agents (SWA) "Arrow Delta" (in stock at NCA)
- **Get a better picture of how different behaviour compared previous lab. Testing of "tradition" HFO (Coastal Oil Spill Program, 2006-2009)**

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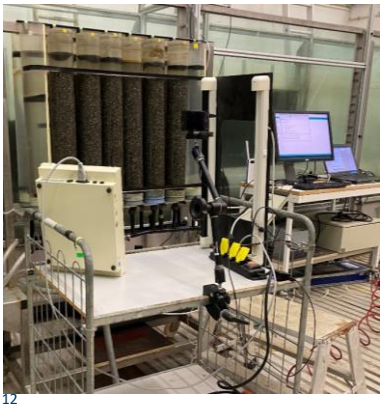
Experimental laboratory shoreline systems

(standard test methods established in cooperation with CEDRE)

1. Sediment Column System



2. Shoreline Sim. System / Ocillating beakers

3. "Flushing" Robot

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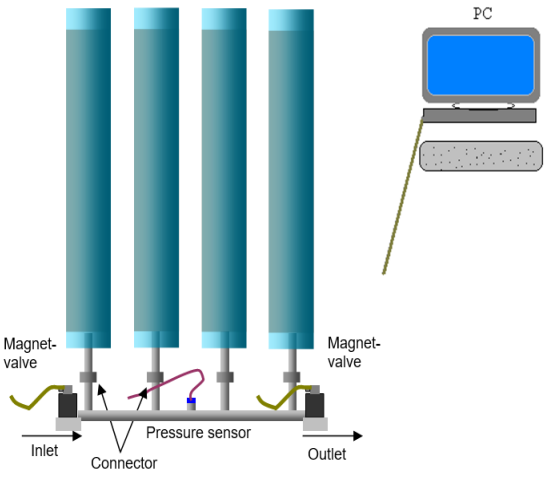
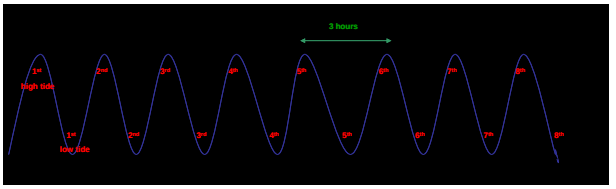
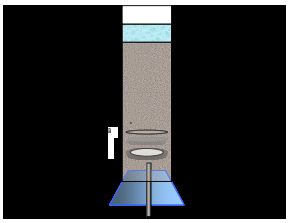
The Sediment Column System

Oil/Emulsion loading: 78.5 g = 10 mm
Sediment grain size: 2-6 mm
8 tidal cycles each 3 h → speed-up: 4 X







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Penetration into sediment at falling tides

MGO 250 °C+ / WRG (weathered diesel oils)

Application on high tide

MGO 250 °C+ / WRG

8th low tide

Using UV light luminescence in darkness in order to see the transparent diesel oils

ULSFO / HDME 50 (viscous, high PP oils)

1st low tide

No penetration

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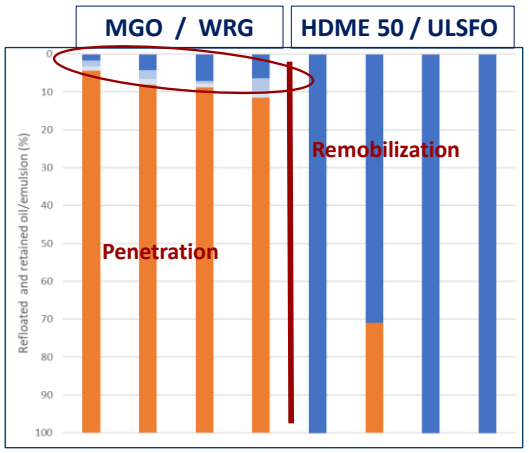
Degree of Remobilization at high tide



HDME 50 and ULSFO (Waxy / high pour point) showed to adhere 1-5 % sediment grains in the remobilization process.

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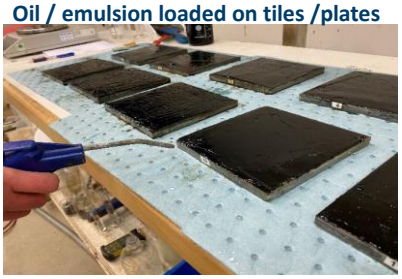
Immobilized oil on "high energy" bedrock shorelines:

Using Shoreline Simulation System with breaking waves

Oil / emulsion loaded on tiles /plates



Oil/Emulsion loading:
4.5 g = 0.2 mm for MGO and WRG
22.5 g = 1 mm for HDME 50 and ULSFO

Conditioning: ~ 24 h

Agent to Oil Ratio (AOR): 1:5
Shoreline washing agent: Arrow Delta
Soak time: 20 min

Exposure: 2 litres seawater
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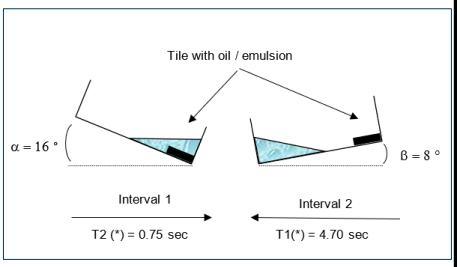
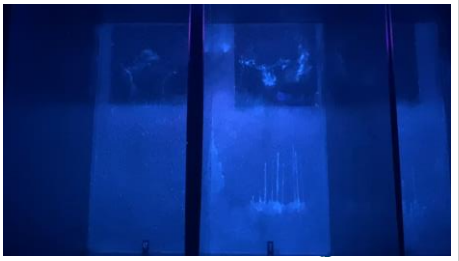
Exposure duration: 30 min

Developed at CEDRE / SINTEF





Using UV light luminescence in darkness

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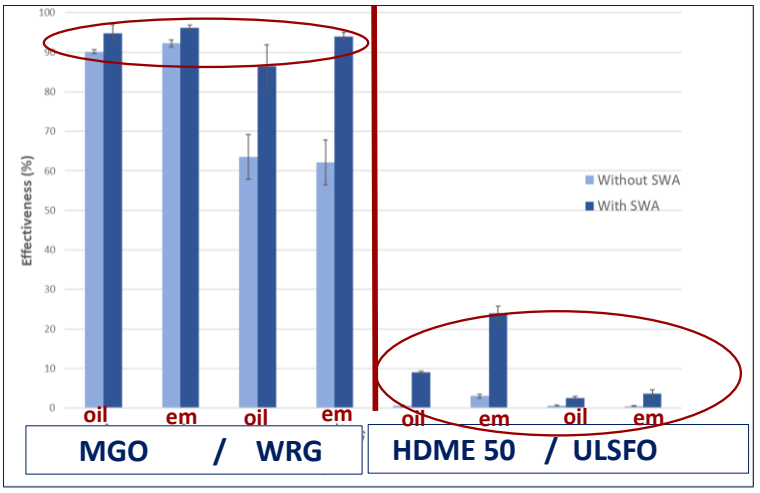
Washout of immobilized fuel oils (residues / emulsions) from bedrock by wave energy (with / without of SWA)



– (using Simulated Shoreline System)

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Effectiveness of washing Immobilized oil on bedrocks:

Using a "Flushing Robot" (SINTEF / CEDRE) standard conditions:

Oil/Emulsion loading:
4.5 g = 0.2 mm for MGO and WRG
22.5 g = 1 mm for HDME 50 and ULSFO

Conditioning: ~ 24 h

Agent to Oil Ratio (AOR): 1:5
Shoreline washing agent: Arrow Delta

Soak time: 20 min

Flushing temperature: 5 °C and 45 °C

Flushing pressure: 4, 15, 30 and 45 bar

Nozzle: SS 25065, spray angle of 25 °, 1.5 mm opening, distance of 30 cm from nozzle to tile

Exposure duration: a few seconds

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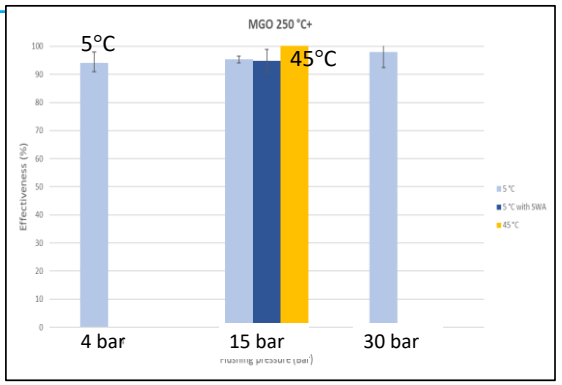
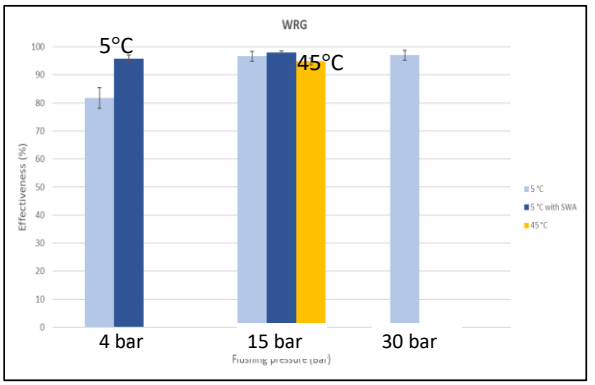
High Effectiveness of washing weathered diesel oils (MGO 250 °C+ / WRG emulsions) (with and without washing agents SWA)

The Flushing Robot





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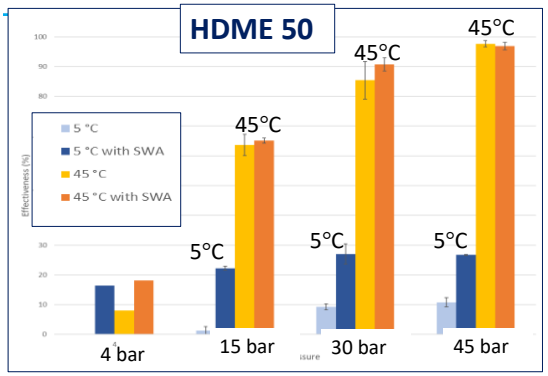
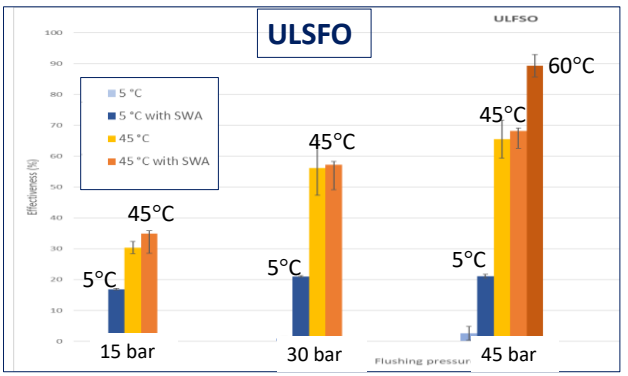
Effectiveness of the waxy and high pour point HDME 50 and ULSFO (RMD): with and without SWA





- Wide variation in effectiveness - depending on washing conditions:
- Washing Temperature at 5 °C : → low effectiveness: < 10%, SWA: → 20 % , pressure: minor effect
- Washing Temperature at 45 °C : → higher effectiveness, pressure: major effect: SWA: minor effect

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Conclusion / Recommendations for further documentation of marine fuels on shore

- A very limited laboratory study using standardized shoreline test systems on 4 different ULSFO oils (< 0.1 % S)
  → gave useful knowledge important for shoreline response
- The span in physico-chemical properties (e.g. viscosity, pour-point) → important for the oils behaviour on shore:
  - Natural washout / remobilization from bedrocks and penetration in sediments
  - Effectiveness of shoreline washing (water temperature and water pressure)
  - Effectiveness of use of Shoreline washing agents.
- Similar study on representative VLSFO (0.5 % S).: > 80 % of day's market of marine fuels:
  (re: NCA: EPPR/PAME report: even wider span in viscosities / pour point of VLSFO on vessels along the Norwegian coast)
- Study effectiveness of other shoreline cleaning agents (shoreline dispersants, bio-remediation)
- Study more long-term fate / weathering on shore: e.g. effect of photo-oxidation → stickiness
- Important: Establish dedicated shoreline test-sites for field testing and validation of laboratory tests
  → will generate reliable data for improving todays model tools used in shoreline oil spill contingency planning / dimensioning of shoreline response that better take into account the span in the properties of todays marine fuel oils
  This is also important for the wide span in properties of crude oils in Norway
  (incl. light crudes, waxy crudes, asphalthenic crudes)

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Thank you for the attention !

- Relevant reports are open and on e.g. NCA home page:
  - Diesel- og hybridoljer | Kystverket - tar ansvar for sjøveien:

Questions?