

■ imaros₂

Petroleum Association of Japan
Oil Spill Workshop 2026

Dr. Silje Berger, 12th February, 2026





KYSTVERKET
NORWEGIAN COASTAL ADMINISTRATION



Our vision

To make the Norwegian coast and sea areas **the safest and cleanest in the world.**



KYSTVERKET
NORWEGIAN COASTAL ADMINISTRATION

Responsibilities and tasks

Coastal Management

Maritime Safety

Environment
Emergency Response



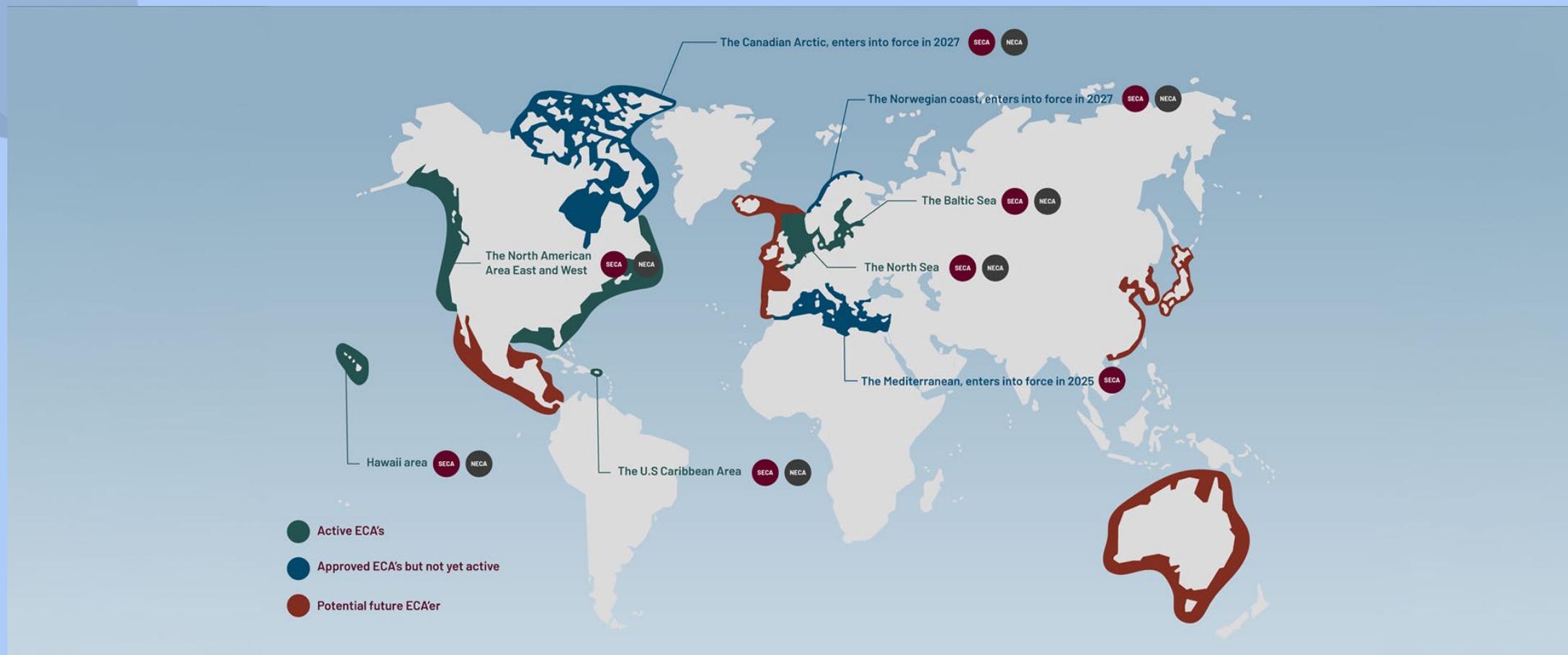
Outline

- Introduction to LSFOS and project background
- Sampling
- Overview of chemical and physical properties of tested LSFOS
- Challenges for responders
- Mechanical recovery – challenges and possible solutions
- Shoreline response
- Knowledge gaps

ECA and Sulphur Cap

VLSFO – Very Low Sulphur Fuel Oils – S < 0,5 %

ULSFO – Ultra Low Sulphur Fuel Oils – S < 0,1 %



Background

- Previous tests and observations
- Results and recommendations from IMAROS project and incidents



imaros₂ Main objectives

- Improve understanding of oil spill behaviour of LSFOS, and consequently decision making on all levels of oil spill response operations
- Improve capacities of mechanical recovery and shoreline response



Project partners



Rijkswaterstaat
Ministry of Infrastructure
and Water Management



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KUSTBEVAKNINGEN

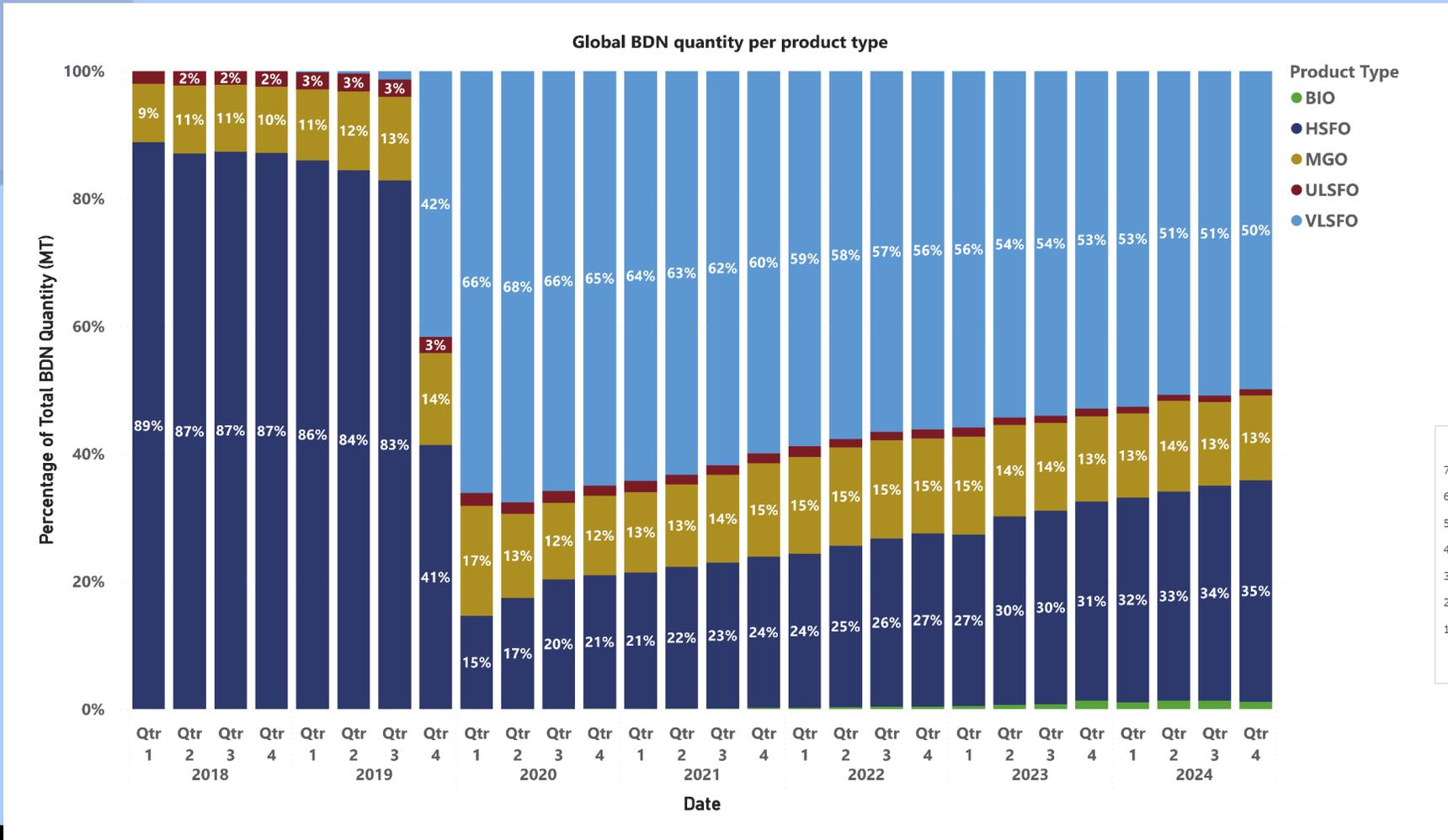


Oil samples

- ~60 different oil companies, bunker suppliers and ports contacted for samples
- Residual LSFOS – different blends
- 16 “small” samples for WP3 chemical characterization
- 3 “large” samples for response testing 2 VLSFO, 1 ULSFO

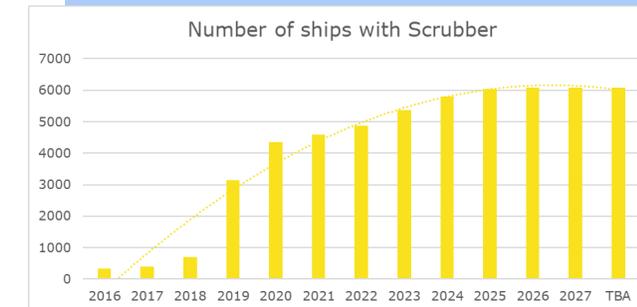


Bunker Delivery Global



Data from VPS

- 2020 IMO Sulphur cap
 - increase of HSFO
 - decrease of LSFO

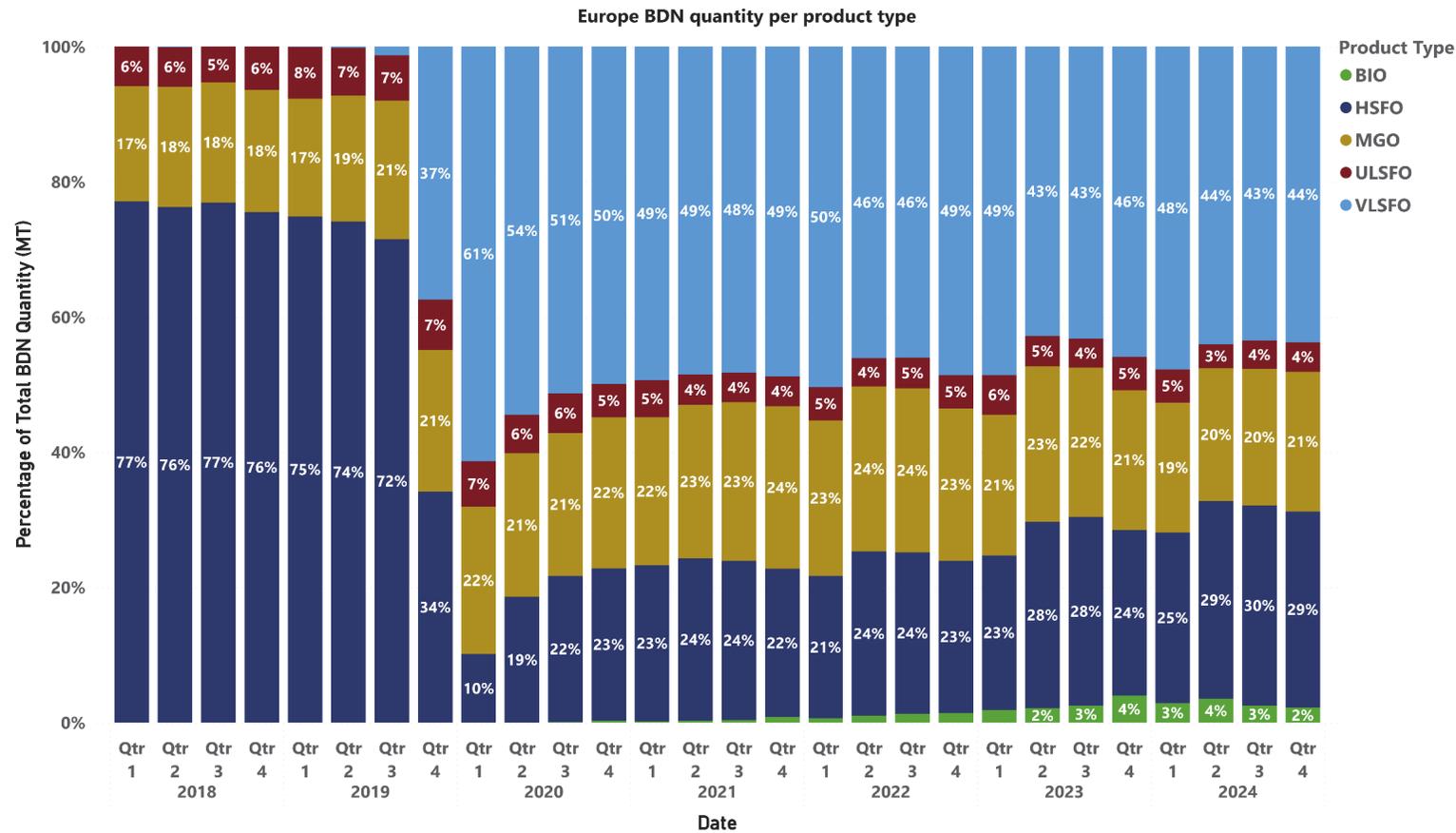


- MGO stable ~14%
- Bio fuels since 2022



Bunker Delivery Europe

Data from VPS



- 2020 IMO Sulphur cap
 - More or less stable fuel market
- MGO sales stable ~22%



Samples

19

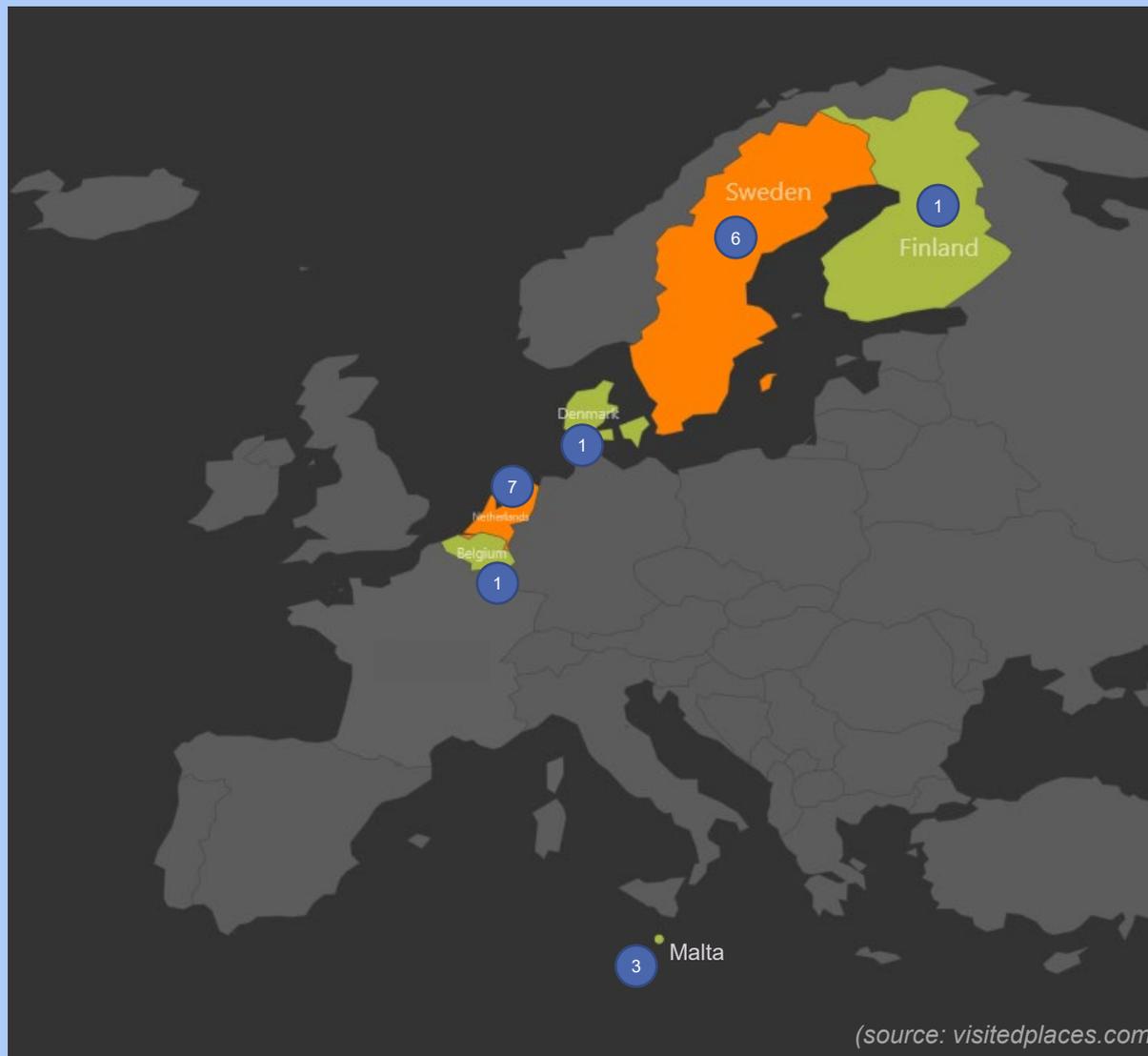
16 small, 3 large

6 countries (FI, SE, DK, NL, BE, MT)

5 ULSFO

14 VLSFO

Refineries or bunker companies



All black residual fuel oils



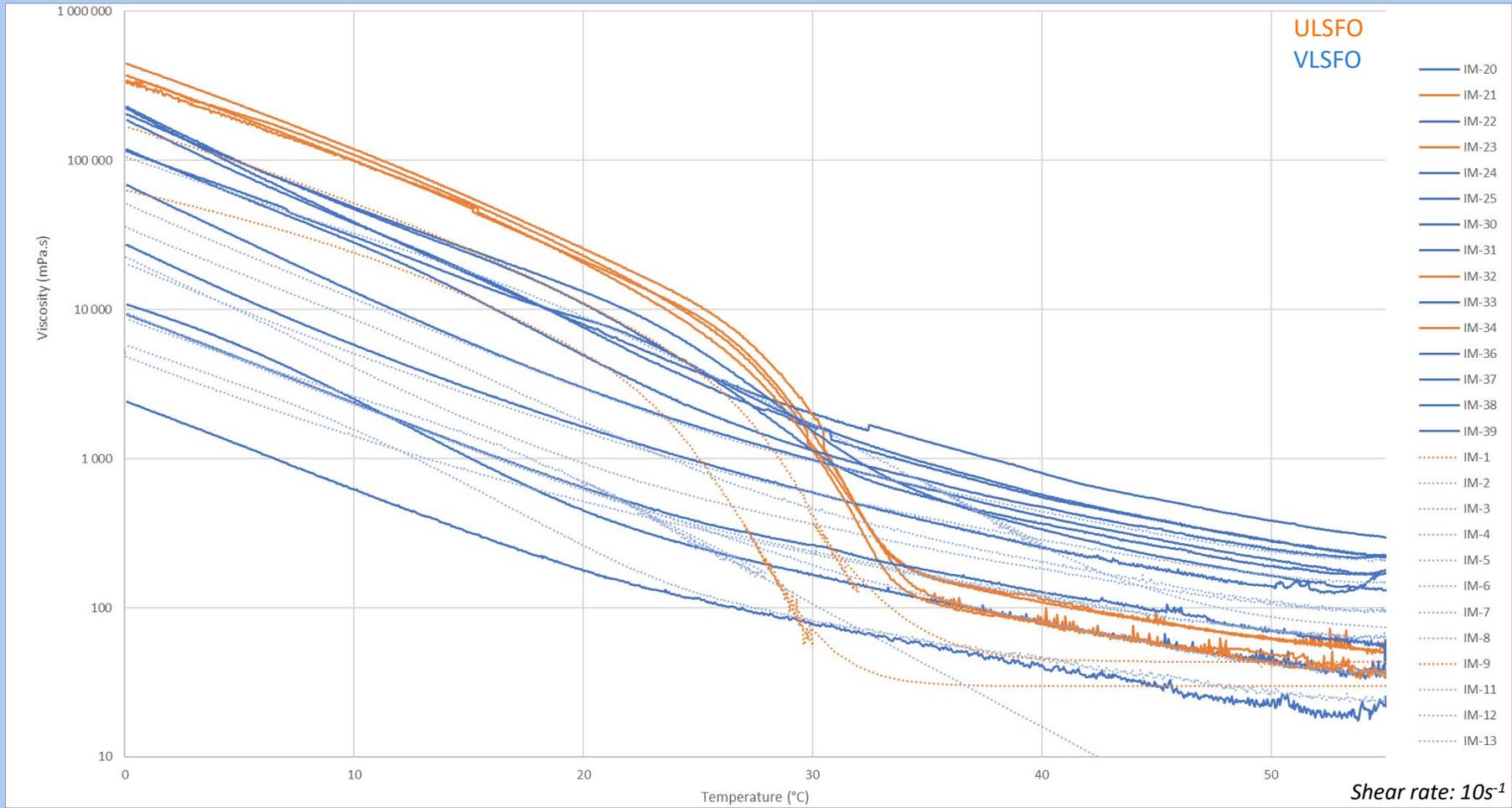
Visual aspect at ~20°C:

- 9 fluid
- 10 not fluid

Viscosity

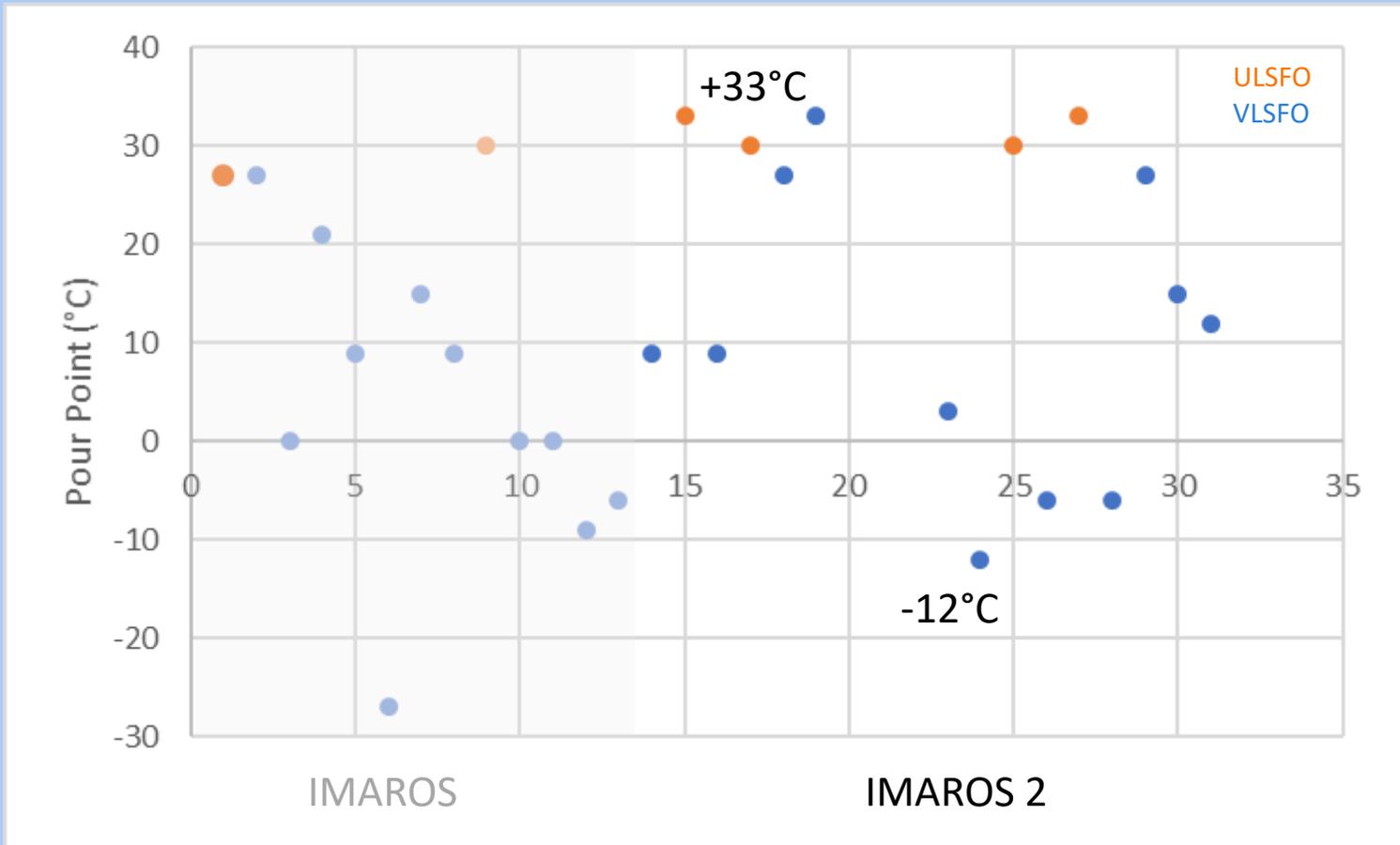
Small samples

Comparison with IMAROS

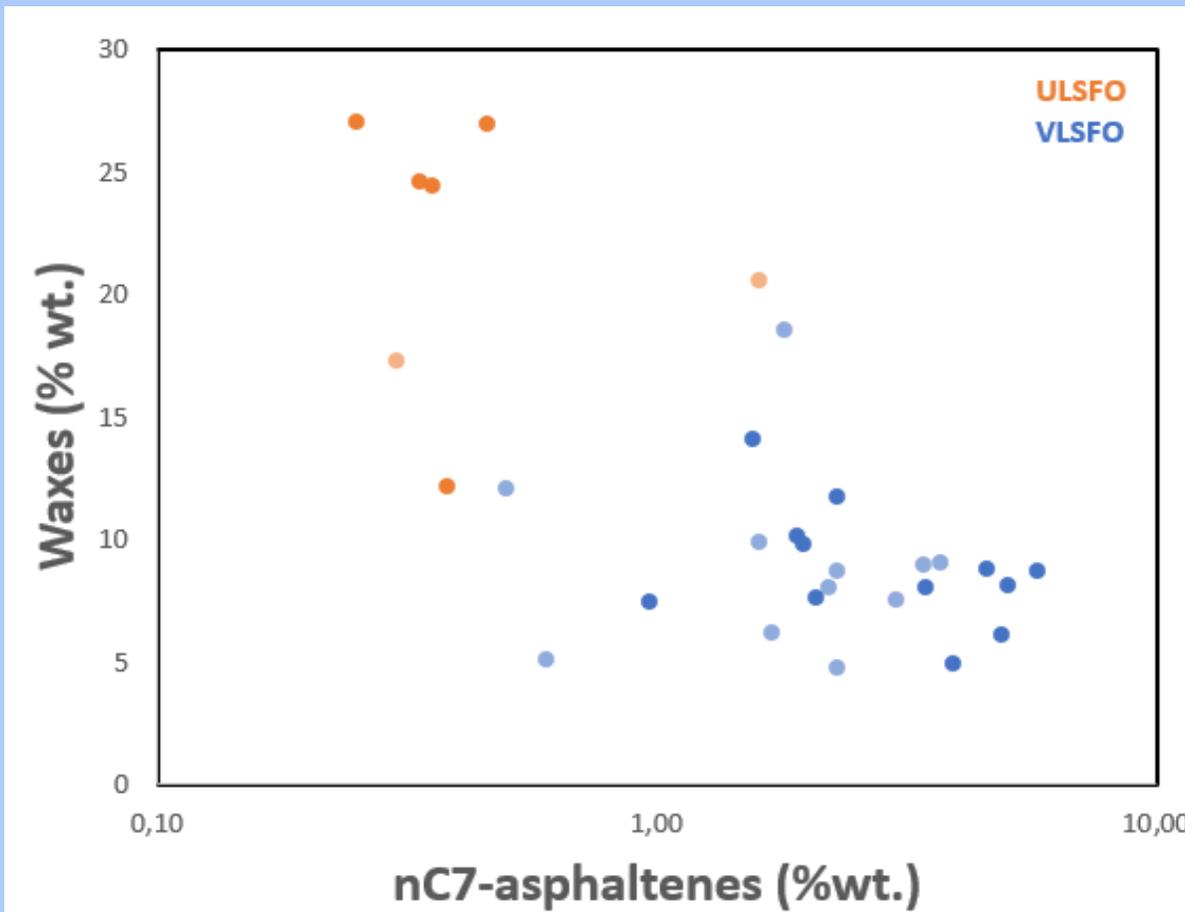
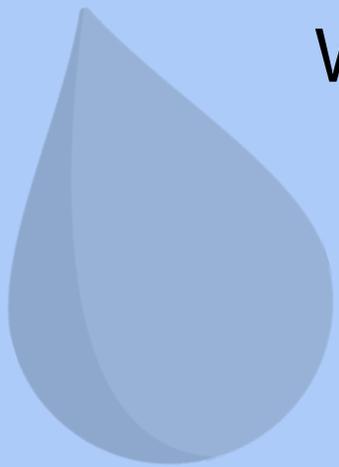


Pour Point

Small samples

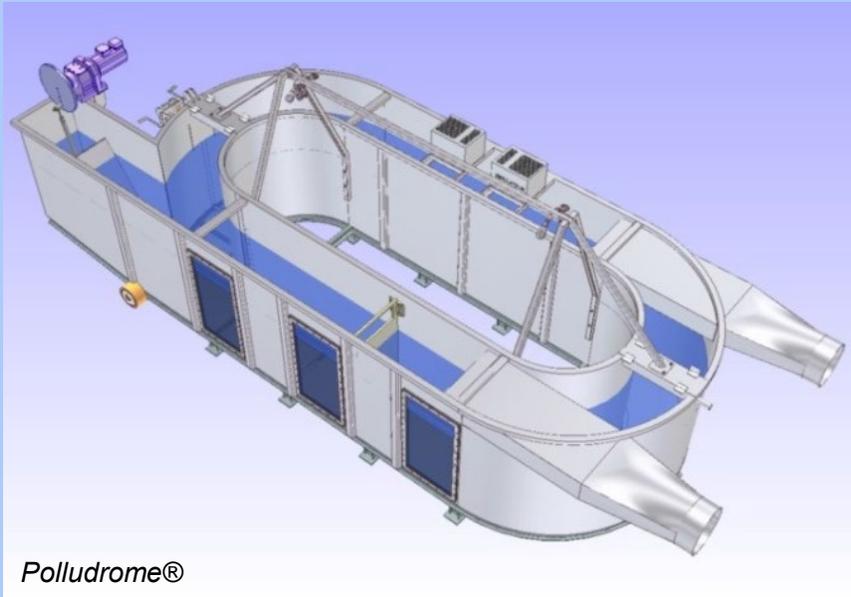


Waxes & Asphaltenes



Weathering

| | Visc. 50°C CoA from suppliers (mm ² /s) | Pour point Cedre (°C) | Density 15°C | Visc. 5°C (10s ⁻¹ , mPa.s) | Visc. 25°C (10s ⁻¹ , mPa.s) | Evaporation rate (% vol.) | Asphaltenes (%) | Waxes (%) |
|--------------|--|--------------------------|-----------------|--|---|------------------------------|--------------------|--------------|
| IM27 (VLSFO) | 322 | 9 | 0.96 | 165 205 | 7 592 | 3 | 2.1 | 7.6 |
| IM28 (VLSFO) | 124 | 24 | 0.94 | 249 952 | 21 221 | 1 | 1.5 | 14.1 |
| IM29 (ULSFO) | 39 | 18 | 0.89 | 42 782 | 331 | 8 | 0.4 | 13.3 |



For each oil, 3 conditions tested

- 5°C in seawater
- 5°C in freshwater
- 25°C in seawater

Weathering – Global observations

At 5°C:

- 1st part:
 - IM-27 and IM-28: oils stick to the walls, no floating oil for a time, can go up to 96h, need to be manually removed from the walls
 - IM-29: one big slick moving but that can hang the walls
- 2nd part:
 - IM-27: with time and emulsification, a slick reassembles and float again
 - IM-28: Stays stuck / no oil free
 - IM-29: The oil freely floats

Real environment: Slicks can either disseminate as small bullets or become even more compact, with slower emulsification process

At 25°C: • IM-27, IM-28 and IM-29: Much more traditional behaviour

Effect of salinity/Freshwater: no major changes. Whatever the salinity, the oil will go in subsurface in case of agitation/turbulences

☐ IM-28, 5°C, SW

+1h



+144h



| | Fresh oil | Weathered oil |
|-------------------|-----------|---------------|
| Viscosity (mPa.s) | 250 000 | 380 000 |
| Density | 0.94 | 0.97 |
| Water content (%) | - | 40 |

Solid / semi-solid slicks with granular aspect
May disseminate
Bullets can slowly emulsify

A continuum of possible rheological behaviours

Viscous liquid

Viscoelastic liquid

Viscoelastic solid + transition to liquid

Viscoelastic solid + transition to liquid, with memory

Elastic solid with low fracture toughness

Elastic solid with higher fracture toughness

Continuous liquid spreading slicks or patches of liquid slicks

“solidish” slicks, possibly broken into large lumps/floes, tarballs or pellets as a function of sea state

Could eventually freeze in small flocks if water temperature much lower than pour point

Main findings oil characteristics

- High variability in the physical-chemical properties of LSFOS (esp. pour point / wax content);
- No flammability issues raised (flash point > 80°C);
- Persistent products (low evaporation);
- Viscosity can highly increase for low-moderate sea water temperatures, especially for ULSFOS;
- Pour point can be subject to uncertainty compared to the data on the CoA, and lead to unexpected behavior;
- Floating oils but depending on the salinity and on the suspended material concentration, some oils may be entrained into the water column;
- At 5°C, LSFOS can fragment in small granular tarballs or form compact slicks;
- With time, slow emulsification of the patches/slicks occurs, and viscosity can reach 400 000 mPa.s;
- At 25°C, more traditional behavior occurs;
- Chemical dispersion seems limited to some fresh oils (IMAROS samples)
- Based on viscosity measurements, recovery is recommended even if challenged for some oils due to high pour points and particular behaviors;

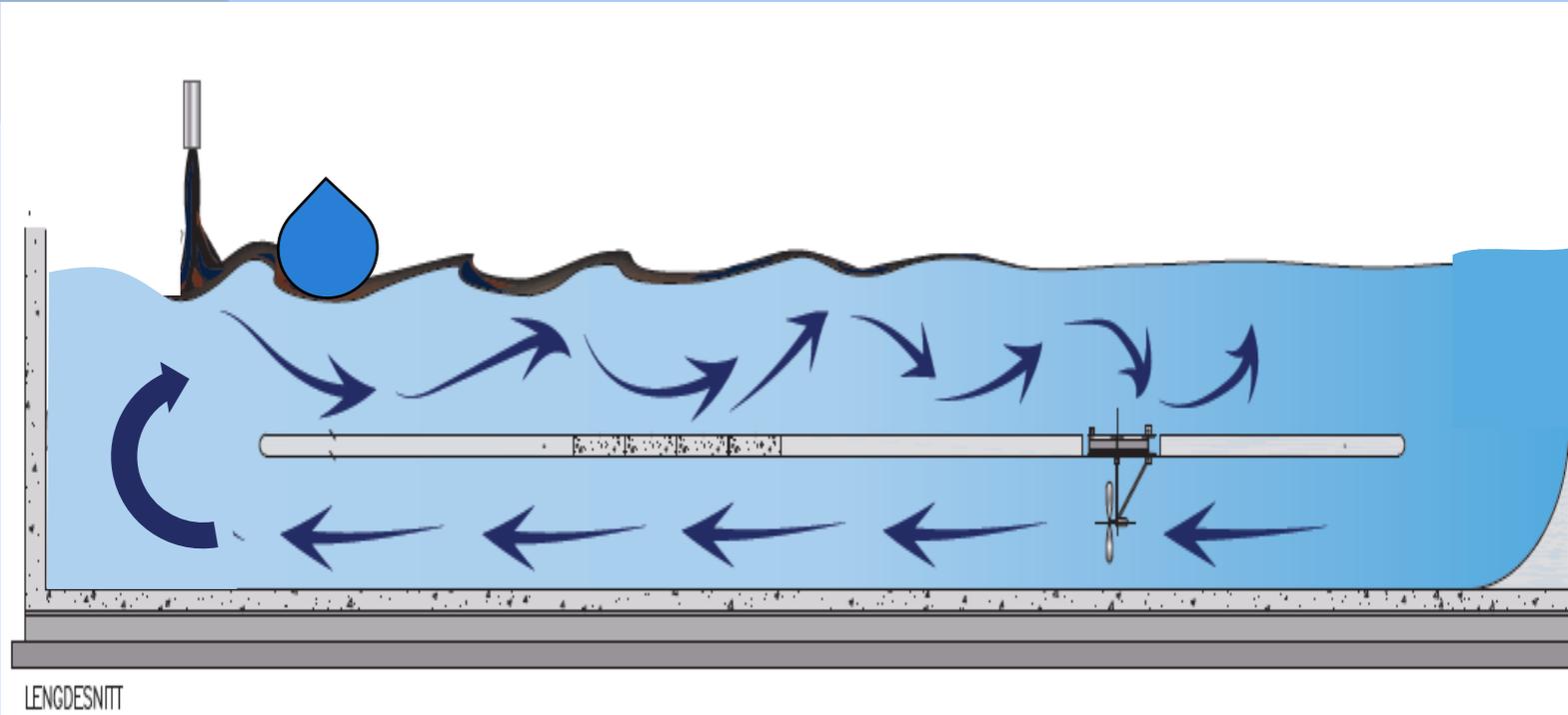
Mechanical recovery

- Producer involvement conference, hosted by Swedish Coast Guard
- Invitation to participate in the project:
 - applications from 11 companies
- Process with all project partners to select the most promising approaches:
 - 3 concepts for testing in Horten (2 trail periods)
 - 2 concepts for testing in Kotka (ice conditions)
 - 1 concept for testing in Horten with modified test procedure
- Measurement of exposure to workers (STAMI)





National test centre of oil spill response equipment



- Length 30m
- Width 7m
- Depth 4.4m
- Current 3 - 4 knots
- Wave height 1.1m

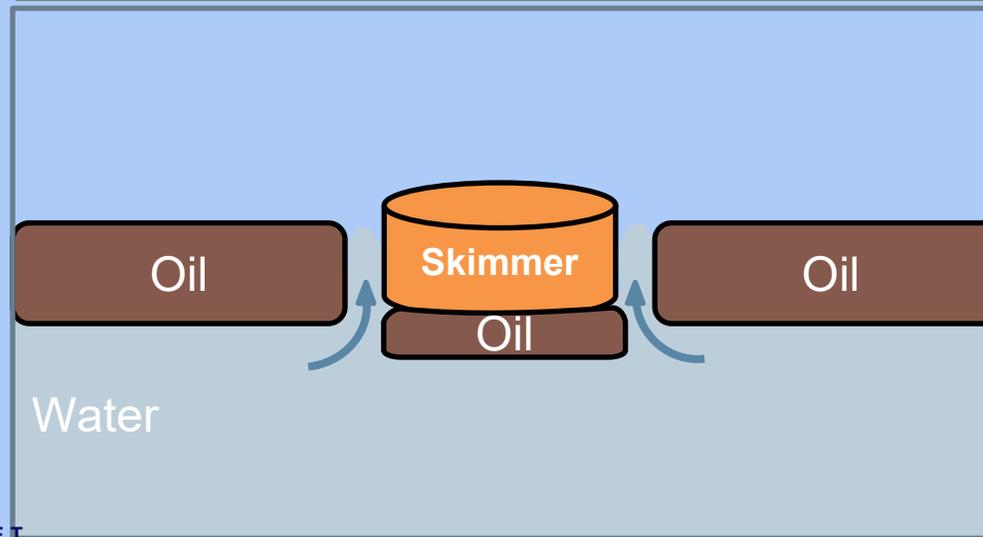
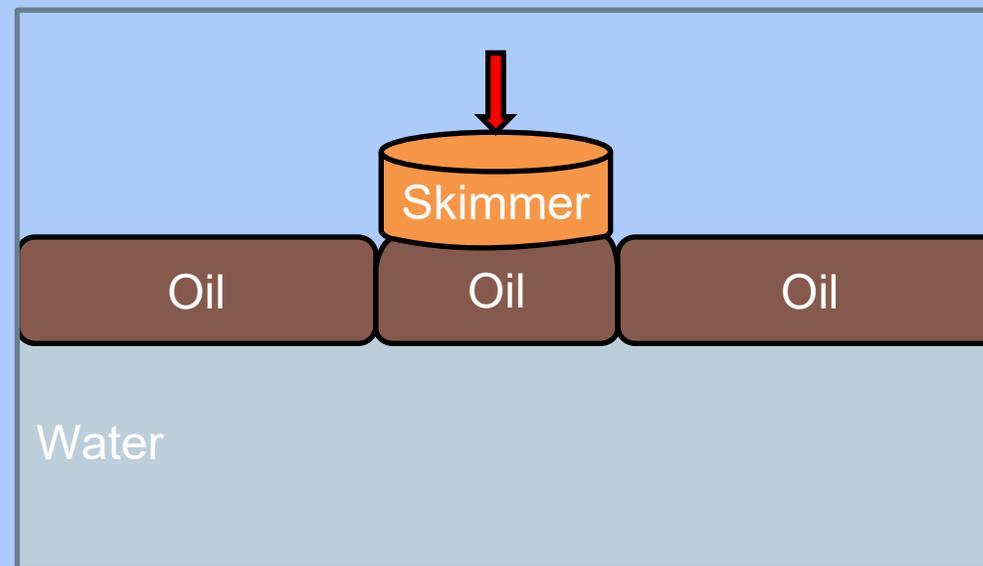
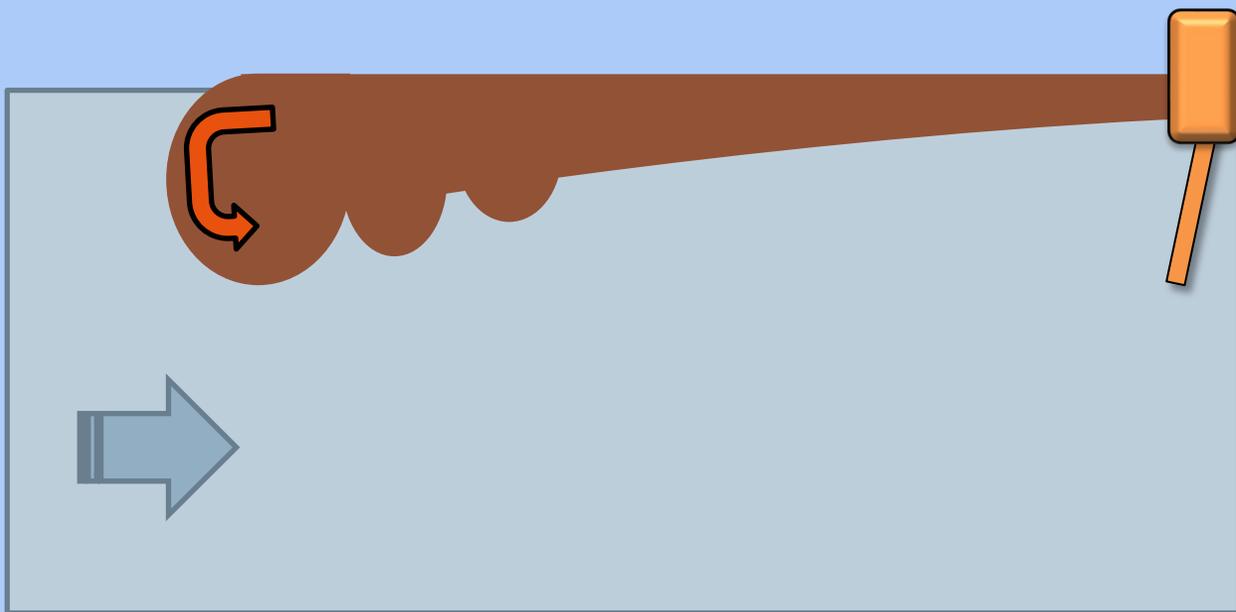
Oil samples

| Imaros 2 ID | Oil type | Viscosity of fresh oil, temp sweep (cP) | | Viscosity of emulsion at 10°C (10s ⁻¹) | Pour point of fresh oil (with max. and min.) |
|-------------|----------|---|------|--|--|
| | | 10°C | 50°C | | |
| IM-27 | VLSFO | 23104 | 282 | 9998 – 42548 | 21 (9, 21) |
| IM-28 | VLSFO | 36277 | 110 | 21386 – 54734 | 30 (21, 27) |
| IM-29 | ULSFO | 932 | 9.6 | 12173 – 18492 | 21 (15, 24) |

Observations on oil behavior



Observations



VLSFO IM-28



ULSFO IM-29



LAMOR LAM 50 with Feeder in IM-28



DESMI Octopus in IM-27



VIKOMA in IM-28



Main conclusions from WP4 - mechanical recovery

- High variability in the physical characteristics causes different behaviour at sea. LSFOs may appear as either fluid, semisolid or solid slick at the water surface. This is highly related to the variability in pour point. Some LSFOs may also appear as small solid lumps (tar-balls) in the water.
- The oil thickness varied greatly within the slick of IM-28 and IM-29 with the highest thickness furthest away from the boom, thus changing the optimal attack point for efficient recovery.
- Several LSFOs showed poor flow properties for skimmers, causing bridging and poor adhesion to skimmer brushes, bands and discs. Implementing thrusters on the skimmers proved essential for overcoming the poor flow properties of the three test oils.
- In the hopper of skimmers, the poor flow properties caused difficulties getting the oil down to the pump. Oil can stick on the sloped sides of the hopper, causing the pump to run dry. Applying energy on the oil in form of heating, mechanical movement or having the hopper and pump closer together helped the oil to slide down to the pump easier.
- From oil-in-ice tests in Finland, recovery of LSFO with poor flow properties showed to be even more challenging in sub-zero conditions with ice present. The presence of ice blocks created difficulties with oil inflow to both skimmer and pump. The use of hot water and steam improved oil flow to the pump and discharge hose.
- Recovery equipment needs flexibility to be able to be prepared for an LSFO spill due to the variability in the behaviour of LSFOs.
 - Flexible recovery equipment includes using actively manoeuvrable skimmers and/or skimmers with multiple configurations (thrusters, ability to change/add brushes, discs, or belts, adjustable operating speed etc.).
 - The challenge of this approach is that the equipment becomes more complex, which places greater demands on the operator.

Remaining challenges and questions

- Temperature (colder)
- Weathering over time
- Individual lumps (varying size)
- Pump capacity (hoses are 100m)
- Emptying the collection tank
- Things we haven't thought about yet

Oil in Ice tests - Kotka, Finland



- Testing of oil skimmers in winter conditions
- Recovery of LSFO from broken ice
- Test conditions mimicking solid ice field that has a fairway broken in the sea
 - Air temperature: $-2,0^{\circ}\text{C}$
 - Water temperature: 0°C

Oil in Ice tests - Kotka, Finland



WP5 – Shoreline responses



T5.1 - Rock cleaning

Assessment of oil adhesion on granite tiles and of efficiency of cleaning with high pressure water washer



T5.2 - Efficiency of cleaning agents

Cleaning agent added to polluted tiles and processed with cleaning procedure



T5.3 - Natural recovery and rock colonisation by biota

Field tests over one year: Oil remobilisation, chemical composition and tiles recolonisation

WP5 – Shoreline responses



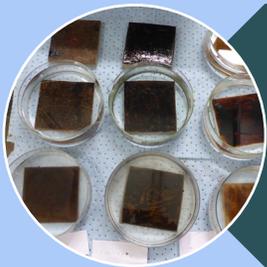
T5.4 - Interaction with sediments

Shoreline test bench: Assessment of oil adhesion / penetration on sand, rock, cobble



T5.5 - Observations on practical cleaning techniques

Assessment of different practical cleaning techniques (manual removal, use of sorbents in « field boxes »)



T5.6 - Release and toxicity of oil absorbed in rocks

Tests on algae and copepods. Culture media: water in contact with polluted tiles

Cleaning of rocky shore



IM-27



IM-28



IM-29



HFO

- High penetration for the 3 LSFOs

| | Mass of oil recovered after drying (g) | Oil recovered after drying (%) |
|-------|--|--------------------------------|
| IM-27 | 2.2 | 72 |
| IM-28 | 1.0 | 36 |
| IM-29 | 0.6 | 24 |
| HFO | 2.5 | 89 |

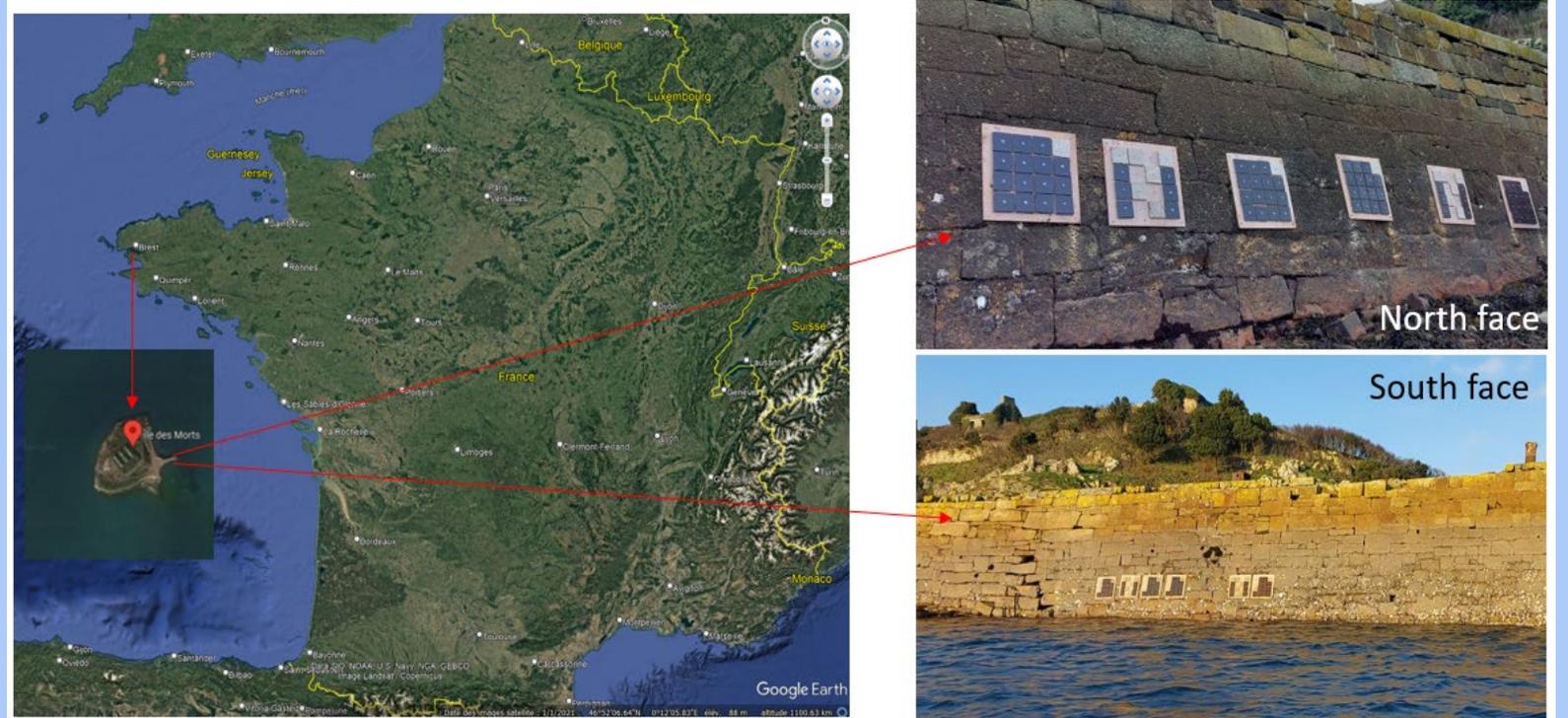
After 5 months of drying

Natural degradation on rocky shore

3 sites

France:

- Granite tiles
- Tiles submerged twice a day
- Subsampling of tiles at different time step over 11 months

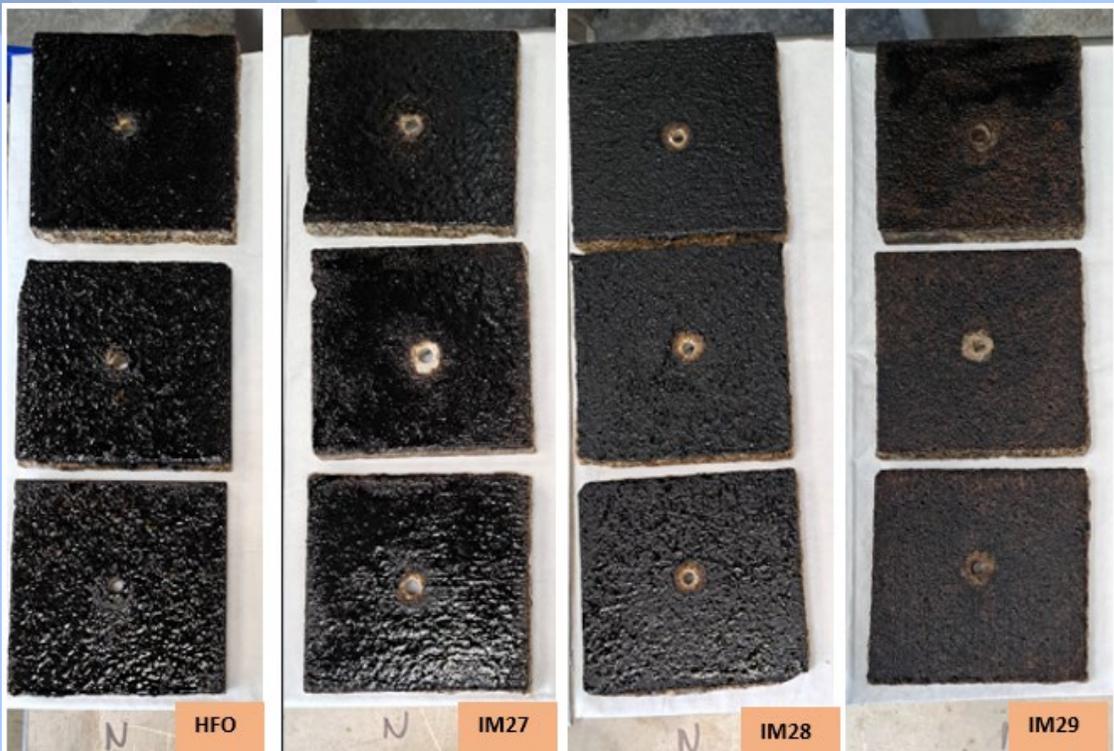


Autorisation from the French Navy / with the support of Ceppol

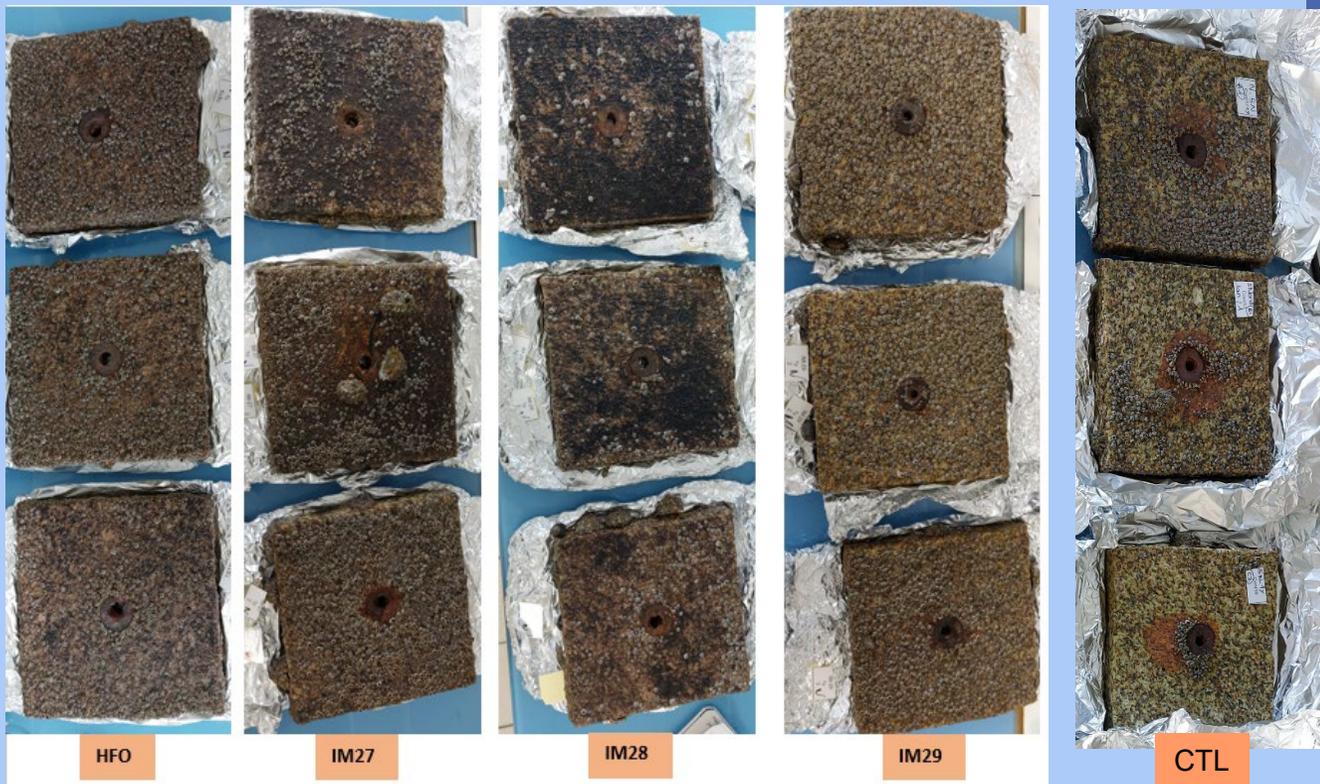
Natural degradation on rocky shore

France
North Face

T0



Tf (+ 11 months)



Testing of practical cleaning techniques



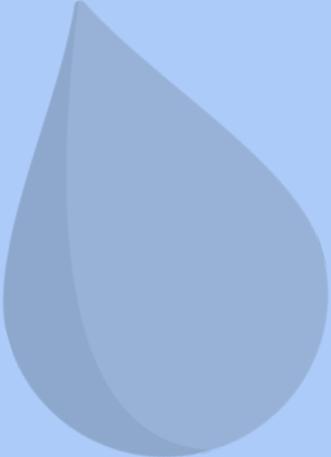
Shoreline clean-up
simulation container

Adjustable angle of the shoreline

Artificial shoreline

Main findings shoreline response

- Depending on the LSFO's nature, weathering time at sea and temperature, LSFOs can interact with the sediment as fluid, small fragmented tarballs or semi-solid viscous slicks;
- Full penetration of fluid LSFOs in sediment beaches may occur;
- Semi-solidified patches on the top of the sediment can also occurs, easily removed before the sun liquifies it;
- Some LSFOs are very sticky, especially to man-made surfaces such as metal, which can make cleaning operations more complicated;
- LSFOs take-off from pebbles can reattach to other substrates if not efficiently flushed with water;
- On rocky shores, penetration may occurs, depending on the LSFOs and the rock nature.
- Efficiency of cleaning with high pressure washer can be very limited but can still be improved by increasing water temperature and/or by using shoreline cleaning agents;
- Natural oil removal from rocks occurs with time, enhanced in warmer climates and helped with wave energy;
- Recolonisation of polluted substrates is observed with time in temperate and warm climates;
- Release of soluble and toxic compounds from lightly polluted hard substrates do not induce higher toxicity than traditional heavy fuel oils.



Thank you for your attention

Visit IMAROS 2:

<https://civil-protection-knowledge-network.europa.eu/projects/imaros-2>

<https://www.kystverket.no/oljevern-og-miljoberedskap/forskning-og-utvikling/imaros-2/>

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