Developing an oil spill response system for the Barents Sea: Laboratory study of oil slick behaviour in sea water in different weather conditions and the effect of dispersants

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1 Introduction

Volumes of oil and oil products transported in the Barents Sea and Kola Bay as well as through the North-East Sea Route increase every year and, according to near term forecast, will continue to grow several times. The increased number of oil carrier vessels will escalate the risk of oil spills in the Barents Sea. Oil spill is a series of natural processes including spreading, evaporation, formation of oil-water emulsion, dispersion of oil in water. In 2006, the Murmansk State Regional Centre for Standardization, Metrology and Testing (MCSM), in cooperation with Statoil, established a laboratory to determine chemical characteristics and analysis of weathered oil. The laboratory is outfitted with equipment for the determination of physico-chemical parameters of oil (density, viscosity, flash point, pour point, hydrocarbon composition, etc.) and a "cold room" to research the interaction of oil with sea water in the temperature range of 5-15°C. Studies of oil are carried out using techniques developed by the Norwegian Institute of Materials and Chemistry (SINTEF), in conditions simulating the presence of oil on sea.

2 Objectives of the research

The objective of this research is testing samples of different oil types, study their physical and chemical properties when released into the sea water, oil slick behavior depending on weather conditions, as well as research on the interaction of chemical dispersants with different types of oil. The research is conducted within the Kolarctic ENPI-CBC project titled "Improvement of the system to respond to spills of oil and oil products through the creation of a data bank of oil". As indicated by its title, the aim of the project is to establish a database of oil samples, which will ultimately aid in devising an optimal clean-up strategy in case of accidental oil spill. The samples used in this study were collected from oil terminals and tankers carriers. Testing of samples of oil from the fields and terminals are held to create a data bank. The test performance data of oil samples will be further used to create a computer model (Figure 1) in order to forecast changes in oil properties under a particular weather condition (sea water temperature, wind velocity, sea waves). This will allows forecasting how a particular type of oil will behave during the spill.

3 Results

Five sample of oil were tested; samples Nos. 1 and 2 are classified as light oil, but their pour point temperature is different, -180°C and -430°C respectively. Samples Nos. 3, 4, 5 are classified as medium-heavy oil, and they are different not only in pour point temperature but also in viscosity and pyrobitumen and paraffin content.

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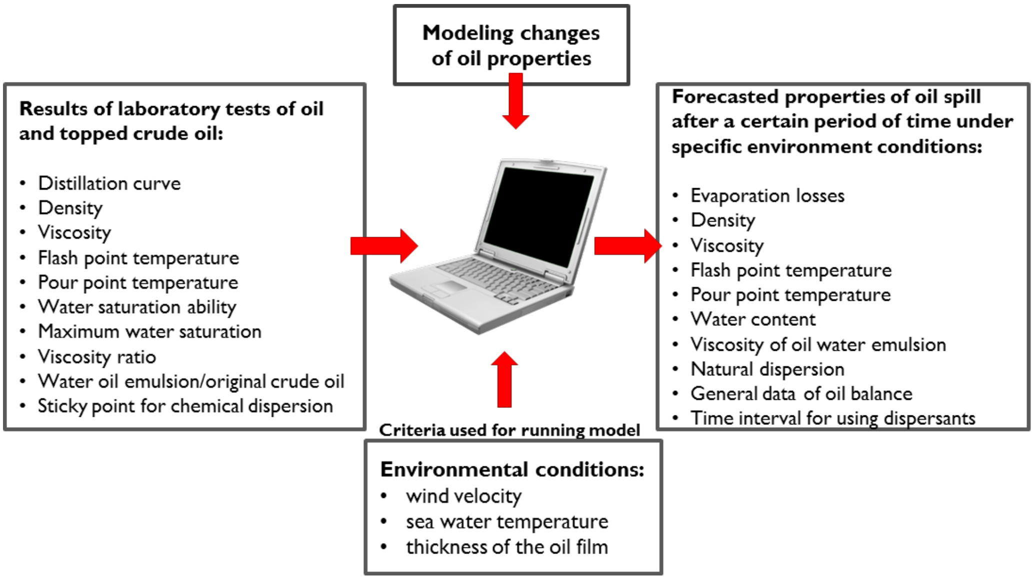

Figure 1 *Forecasting changes oil properties under various weather conditions.*

3.1 Flash point temperature

If the oil spill has the flash point temperature lower than the temperature of the seawater, it could result in inflaming. Figure 2 illustrates that the light oil (sample No. 2) can start inflaming within 30 minutes after the initial time of the oil spill.

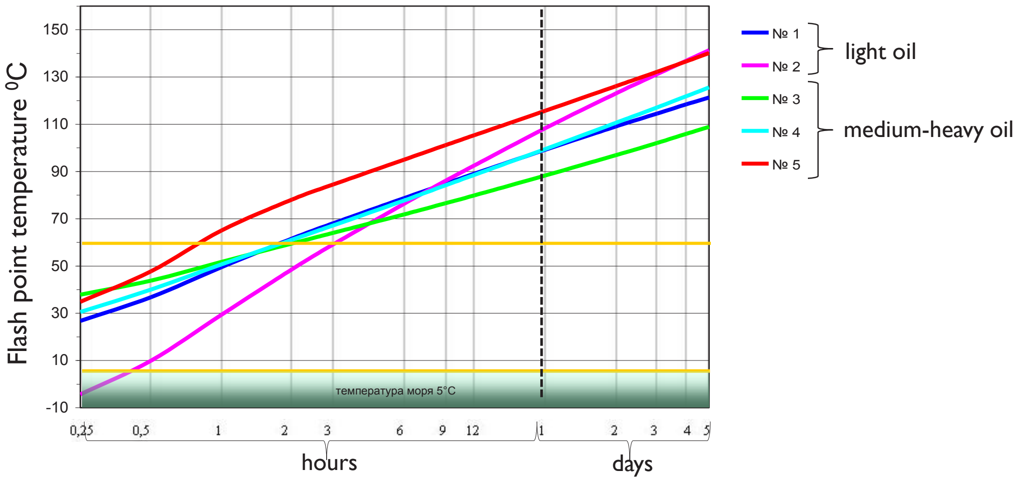

Figure 2 *Flash point temperature.*

For every sample, there is the time frame within which oil spill collection is ill advised as it can result in explosion inside the holding tanks of oil carrier vessels. Only when the flash point temperature is below 600°C can the oil spill be safely collected. Table 1 summarizes the time after which oil spill collection is safe.

Table 1 *Time period for safe collection of oil spill.*

	No. 1	No. 2	No. 3	No. 4	No. 5
Safe collection	after 2 hours	after 3 hours	after 2 hours	after 2 hours	after 1 hour

3.2 Emulsion viscosity

Measuring viscosity allows forecasting possible leak from harbour boom and choose the optimal oil skimmer type. There is a risk of leak from boom fencing for oil emulsion with viscosity under 1000 mPa·s. A mop skimmer is used for oil emulsions with viscosity from 1000 mPa·s to 20 000 mPa·s; for oil emulsions with higher viscosity, vane type skimmer is recommended. Figure 3 shows that, for 2 - 2,5 hours after the oil spill, emulsions from oil samples Nos. 2, 3, 4 can escape from boom fencing and, after that period, the emulsion can be cleaned with a mop skimmer.

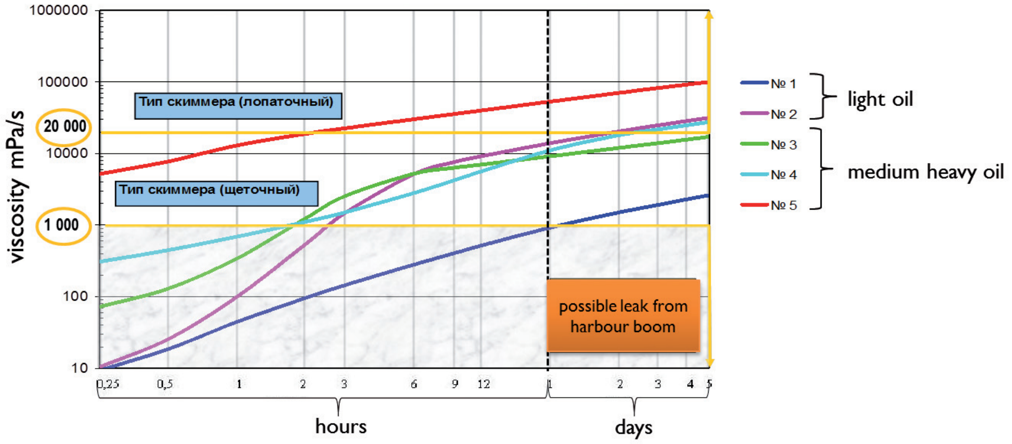

Figure 3 *Emulsion viscosity.*

Emulsion from sample No. 1 can be leaking for 1 day after the spill. Emulsion from sample No.5 is not leaking from boom fencing and can be collected right after the spill within 2 hours with mop skimmer, later a vane skimmer will be more useful. Table 2 summarizes the emulsion viscosity of samples after 1h, 1 day and 5 days.

Table 2 *Emulsion viscosity (mPa·s) of samples after retention times of 1h-5 days.*

	No. 1	No. 2	No. 3	No. 4	No. 5
1 hour	40	100	500	700	14000
1 day	900	15000	10000	12000	40000
5 days	2800	32000	20000	29000	100000

3.3 Water saturation

After the spill, the oil starts mixing with seawater leading to increased volumes of the oil spill. Figure 4 shows the amount of water saturated by the oil.

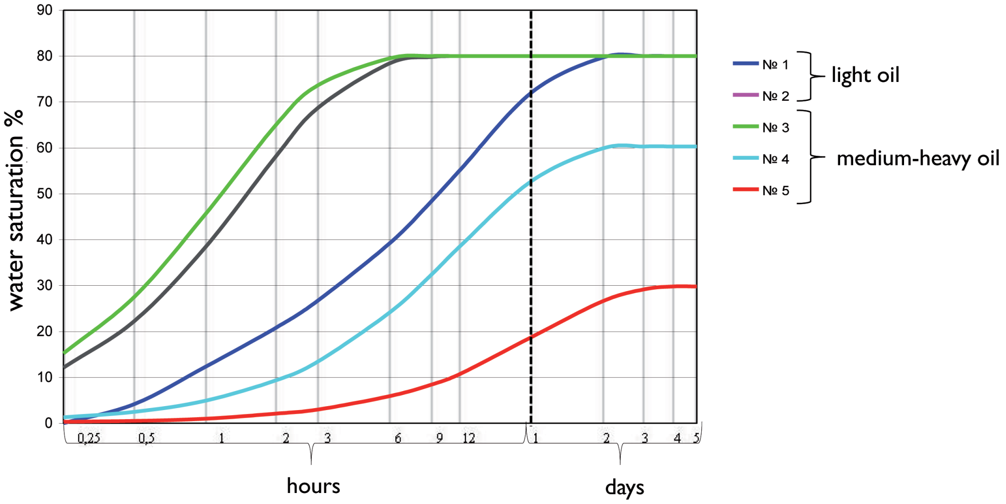

Figure 4 *Water saturation.*

During the first day, samples Nos. 2 and 3 saturate 80% of seawater, sample No.1 saturates 73%, No.4 53%, and sample No.5 only 17% of seawater. Table 3 summarizes the progressions of saturation up to 5 days.

Table 3 Water saturation (%) of samples after retention times of 1h-5 days

	No. 1	No. 2	No. 3	No. 4	No. 5
1 hour	13	37	46	5	3
1 day	73	79	80	53	17
5 days	80	80	80	60	30

3.4 Residuals of oil on the sea surface after natural evaporation and dispersion

Natural processes such as evaporation and dispersion will reduce the amount of oil spill over time. Figure 5 illustrates what percentage of crude oil will remain on the sea surface from total amount of oil initially spilled at the temperature of +5°C and wind velocity of 10m/sec. The amount of oil from sample No.1 will decrease to 10% during one day, while sample No.5 decreases to 63%. Table 4 summarizes the forecasted residuals of oil on the sea surface from 1 h to 5 days.

Table 4 *Forecasted residuals of oil on the sea surface (%).*

	No. 1	No. 2	No. 3	No. 4	No. 5
1 hour	67	69	87	83	85
1 day	10	27	50	45	63
5 days	0	5	15	14	32

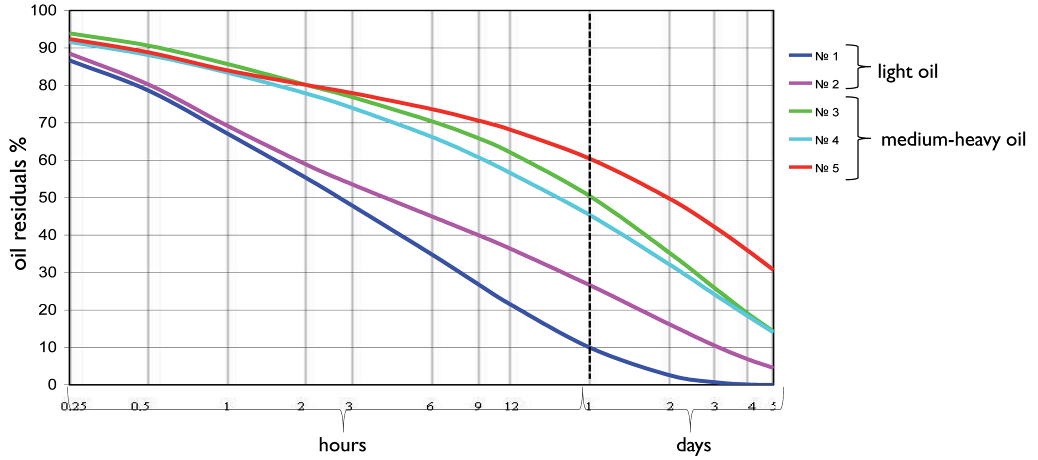

Figure 5 *Residuals of oil on the sea surface after natural evaporation and dispersion.*

3.5 The ability of oil to hold water

The ability to hold water can be a crucial factor during the collection of emulsion into holding tanks of oil carrier vessels. Figure 6 shows for samples No. 1, 2 and 5 the stability of water and oil emulsions and the effectiveness of the demulsifying agent.

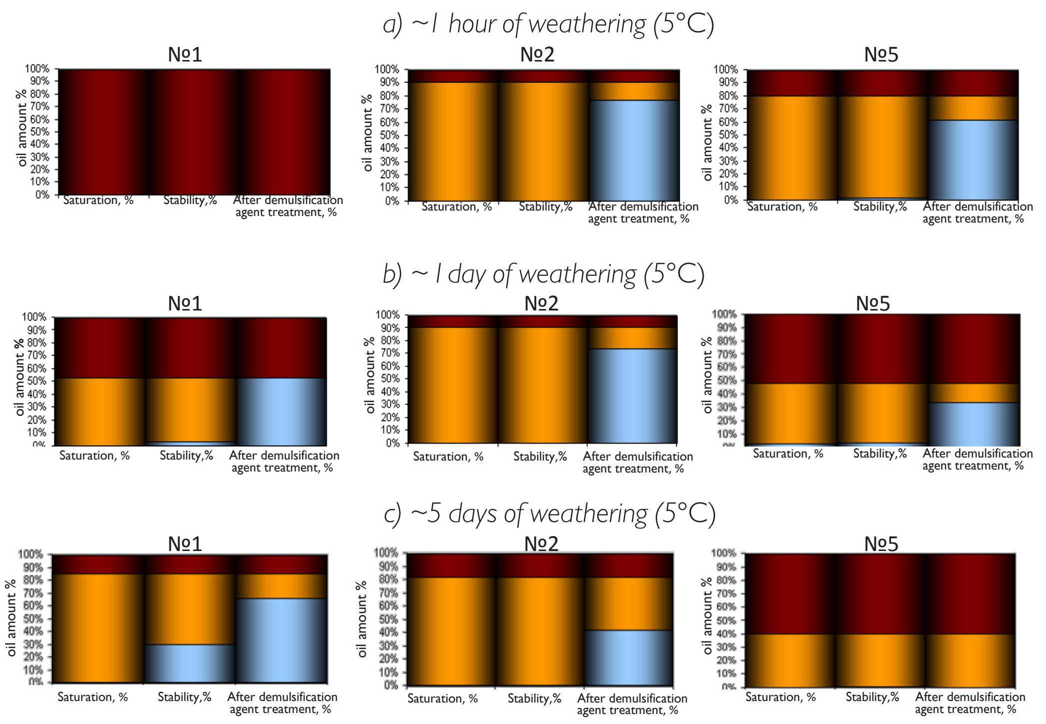

Figure 6 *The saturation rate and stability of oil-water emulsion and the effect of demulsification after a) 1 hour, b) 1 day and c) 5 days of weathering.*

Oil sample No.1 does not saturate water in the first hour and does not produce emulsion. One day later, the oil saturates 53% of water; the oil in water emulsion is stable, after sedimentation only 3% of water released. The demulsifying agent will release all the water. In 5 days, oil No.1 saturates 85% of water, emulsion is relatively stable, after sedimentation 30% of water released, and the demulsifying agent will release 66% of water.

Oil sample No.2 saturates 91% of water in the first hour, the emulsion is stable, after sedimentation no water is released, and the demulsifying agent will release 77% of water. Five days later, the oil saturates 82% of water, after sedimentation still no water is released, and the use of demulsifying agent will release only 42% of water. This illustrates the remarkable difference between the two light oil types.

The medium-heavy oil sample No.5 saturates 80% of water in one hour, oil in water emulsion is stable only 2% of water is released and after sedimentation, and the use of demulsifying agent will release 34% of water. Five days later, the oil saturation does not increase, but the demulsifying agent is no longer effective, as no water is being released from the emulsion.

3.6 The efficiency of dispersant use

The oil spill can be cleaned up by chemical method, using dispersants, which can be diffused from vessels or from air. The efficiency of dispersant use depends on oil viscosity, pour point temperature and wind velocity. Figure 7 illustrates the window of opportunity for two medium-heavy oil samples Nos. 3 and 5.

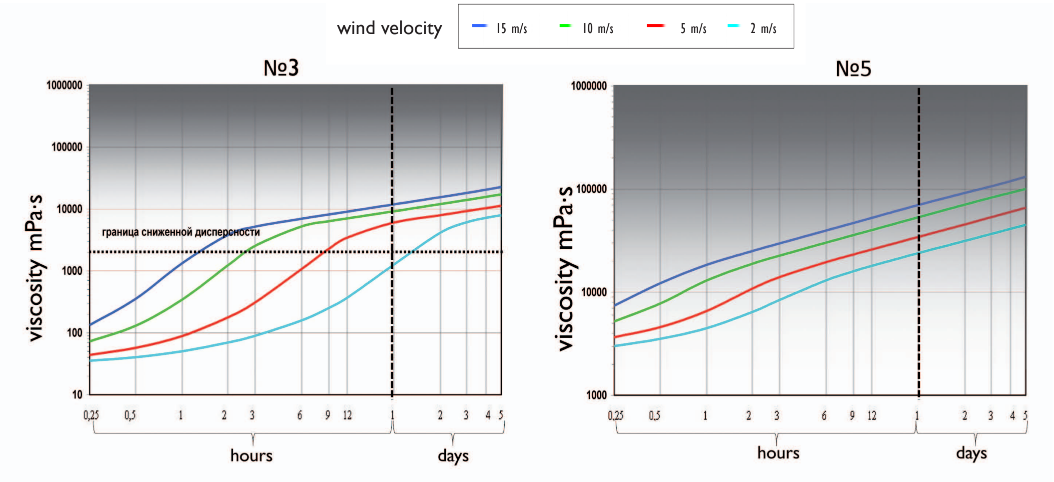

Figure 7 *The efficiency of dispersant use*

For sample No.3 at the temperature +5°C the dispersant can be used at any wind velocity, although from wind velocity of 2 m/s to 15 m/s, the window of opportunity decreases from 1,5 days to 1,5 hours. However, for sample No.5, the use of dispersant is not reasonable, due to its higher viscosity and higher pour point temperature.

4 Relevance of the study

The results of this study contribute to establishing an oil database and determining the efficiency of dispersant use. This will aid in devising a strategy for oil spills clean-up. In case of an accident, oil samples from the carrier tankers are tested to identify oil type. Further, the databank will forward oil specific data to Hydrometeorology services for forecasting oil spill behaviour, which, in turn, can help determine rescue services, instruments, force and means to react adequately and work efficiently during the elimination of oil spill. Further plans include setting up new laboratory facilities, enabling the study of oil at 0°C temperature, training for testing procedures and proficiency in testing to identify polluters.

Acknowledgements

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