Dispersant effectiveness testing of crude oils weathered under various ice conditions

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ABSTRACT

In order to get more precise understanding of the potential for use of dispersants in ice covered areas, an extensive study of the effectiveness and dispersibility of oils weathered under various spill scenarios and ice regimes has been carried out.

The chemical dispersibility of five oils representing different categories of crude oils (naphthenic, asphalthenic, waxy and paraffinic) has been investigated as function of weathering up to one week under different ice conditions (0, 30, 50, 70 and 90% ice coverage) using the SINTEF meso-scale flume weathering basin (Brandvik et al., 2010). The dispersibility testing included both *ex-situ* dispersant testing of oil samples taken during the weathering in the flume, using a standard effectiveness test method (the MNS- test) and *in-situ* treatment in the flume at the end of each experiment.

The results from this systematic series of dispersibility testing, have revealed that several oils can have a longer “operational time window" for use of dispersants in ice covered water compared to open water, because the weathering processes are slowed down in ice. Some oils spilled in high ice coverage conditions remain dispersible for several days / weeks after release. The flume basin experiments for the naphthenic Troll crude oil were verified through a field trial in the Barents Sea. In one of the experiments, 7m^3 of Troll crude was allowed to drift and weather for one week in high ice coverage (70 – 80 % ice) before dispersants were applied from a vessel using a new manoeuvrable spray arm customized for application on oil in ice coverage water. After the dispersant treatment, energy / turbulence using propeller washing and MOB boat water jets to was used to cause the dispersion process of conversion into very small oil droplets. These mixing methods proved to be highly efficient (Daling, et al., 2010).

Introduction / Background / Objectives

Over the past decades, dispersants have successfully been used on both tier 2 and 3 oil spills on many occasions, like the Sea Empress incident in Wales in 1996 (e.g. Law. 2010). During the DWH incident in the Gulf of Mexico in 2010, application of dispersants (both surface and subsea) played a key role in the effectiveness of the response (e.g. Lehr et al, 2010). In Norway, focus has the last years been on development of high capacity vessel application systems. Also strategies for aerial FLIR-recording guidance with down-link to the application vessels have been developed and successfully used in dispersant treatment of accidental oil spills in total darkness (e.g. Jensen et al., 2008)

The use of dispersants may also have a great potential in ice-infested waters, but have not been sufficiently documented or operationally tested during large-scale field experiments. Therefore, considerable skepticism has exists concerning the viability of using dispersants on crude oils spills in very cold- and ice-infested water conditions. Various laboratory and basin testing over the past decades have been completed with mixed results (e.g. Mackay et al. 1979, 1980, Cox et al. 1981 and Brown et al. 1996). Series of large-scale basin tests in the Ohmsett facilities have, however, demonstrated that oil spill dispersants may be effective in dispersing oils at cold temperatures and energetic breaking wave conditions (Belore et al 2009). A review of both bench-scale and larger wave-tank studies on the effectiveness of oil spill dispersants in Arctic conditions has been given by Lewis and Daling (2007a).

The most critical parameters for the operational use of dispersants under Arctic / ice-covered conditions are:

1. Dispersant performance and properties under relevant conditions (salinity, temperature, oil type).
2. Oil's dispersibility and weathering properties at low temperatures.
3. Access and contact between dispersant and oil.
4. Sufficient energy for the dispersion process.

During a 4-year research project, all four of these fundamental parameters have undergone scientific studies in order to better define and extend the potential for use of dispersants as an operational response tool in cold and ice-covered areas. In this paper, we focus on the laboratory and basin studies connected to the first two topics. The main objective has been to study the dispersant effectiveness as a function of oil type, weathering degree and ice concentration. This in order to obtain a more precise understanding of the “window of opportunity” for operational use of dispersants under various spill situations in ice-covered waters.

The more operational aspects (parameters 3 and 4) has included development and field testing of a spray system for optimal application of dispersant on oil spills in ice and strategies for generating the required local turbulence needed to fulfil the dispersion process is described in Daling et. al. (2010a and b)

This study has been an integrated part of a Joint Industry Program to develop and advance the overall knowledge, methods and technology for oil spill response in Arctic and ice-covered waters ("Oil in ice" JIP). The research program started in 2006, experiments were finalized with large-scale field trials in the Marginal Ice Zone in the Barents Sea in 2008 and 2009. The JIP summary report (Sørstrøm et al., 2010) gives an overview of the 4-years research program.

Results

This paper gives only some selected examples of the results from the weathering flume basin testing. Figure 1 shows an overview of the weathering (viscosity) of the five different crude oils vs. dispersibility (*ex-situ* testing using the MNS test and Corexit 9500) with no ice and with high ice coverage in the basin. As illustrated by the red arrows, the "clusters" of viscosities for the different oils become generally lower when weathered in high ice conditions compared to no ice (at $0^{o}C$) , and that this results in a higher dispersant effectiveness for all the oils except the waxy Norne crude, that show a general low dispersibility in cold conditions.

Figure 2 gives an example of the effectiveness of *in-situ* dispersant treatment after weathering for one week in the flume basin when terminating the 5 experiments with different ice conditions (0, 30 , 50, 70 and 90 % ice) with the naphthenic Troll crude oil. There is an increase in the dispersant effectiveness with increasing ice coverage due to a more slow weathering (evaporation, emulsification) process with increasing ice coverage present. At 90 % ice, there is, however, a reduction in the dispersant effectiveness. This is not due to a less dispersible oil, but due to lack of turbulence / wave energy, means there is a need for artificial turbulence to fulfil the dispersion process.

These findings from the flume basin experiments became very useful when designing the strategy for the large scale field testing in the Barents Sea in 2009. Figure 3 gives an overview of the application strategy used: 1) Dispersant treatment followed by artificial energy / turbulence using " 2) Propeller / thruster washing and 3) MOB boat water jets to fulfil the dispersion process into very small oil droplets.

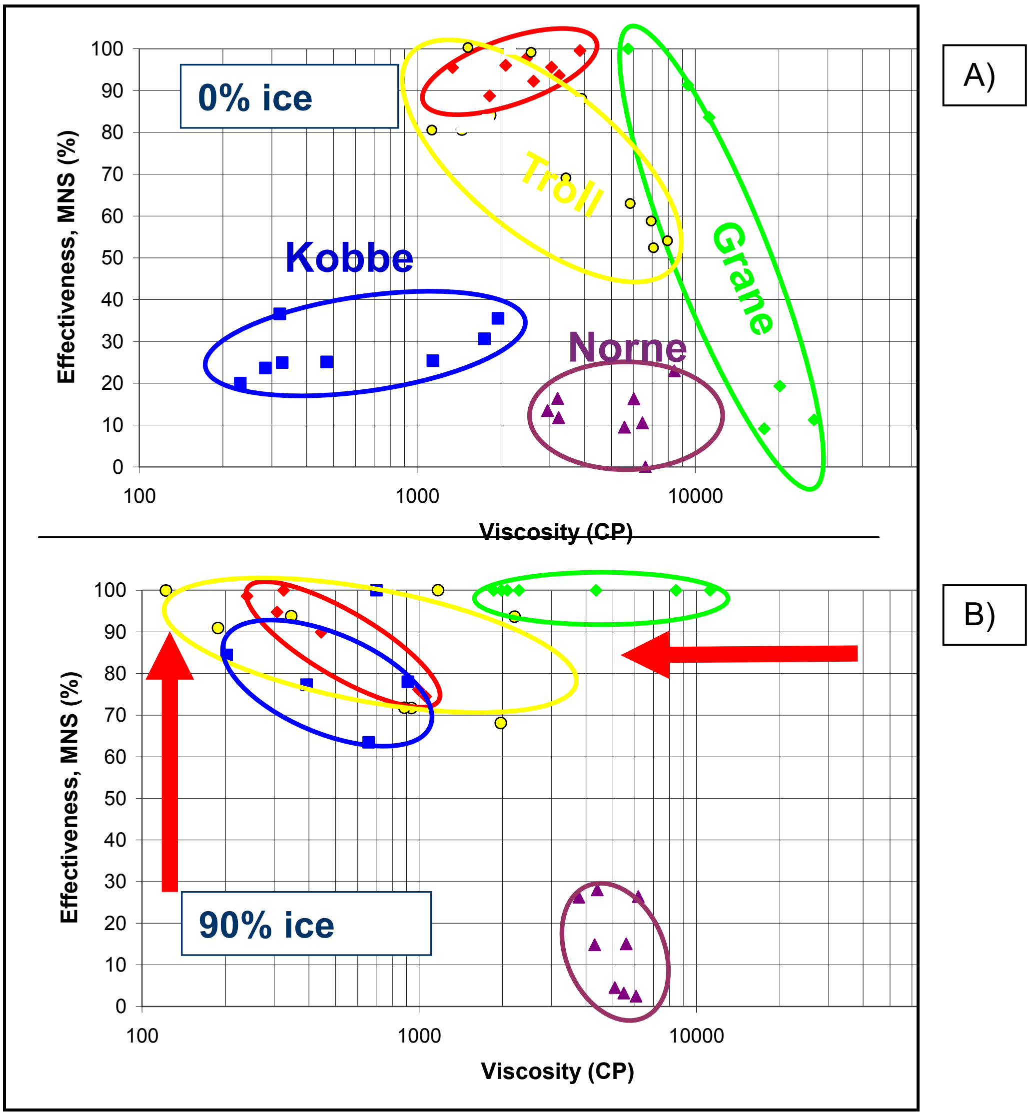

Figure 1: "Clusters" of viscosity vs. dispersant effectiveness (MNS test and Corexit 9500) of the different oils during one week weathering in the SINTEF flume basin. A) No ice, B) 90% ice coverage

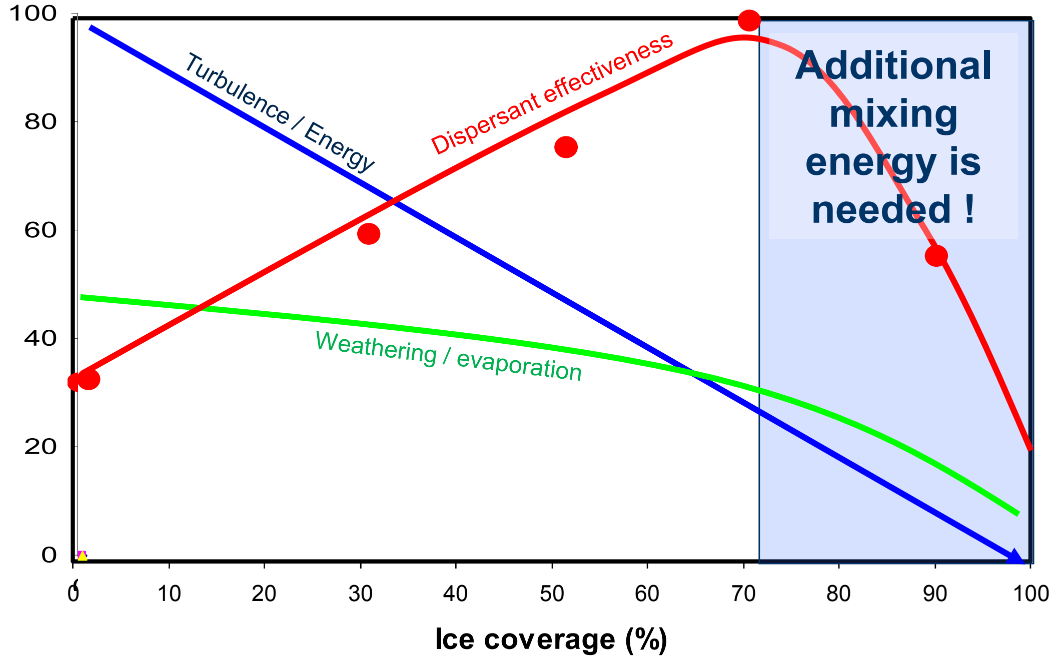

Figure 2: Effectiveness of in-situ dispersant treatment after one week weathering in the flume basin for the five experiments with the naphthenic with Troll crude oil under various ice coverage.

Figure 3: Overview of the dispersant application strategy used during the field trial in the Barents.Sea

Figure 4 shows the container-based and maneuverable spray arm under dispersant operation in the large-scale field experiment in the Barents Sea (Daling et al. 2010a/b).

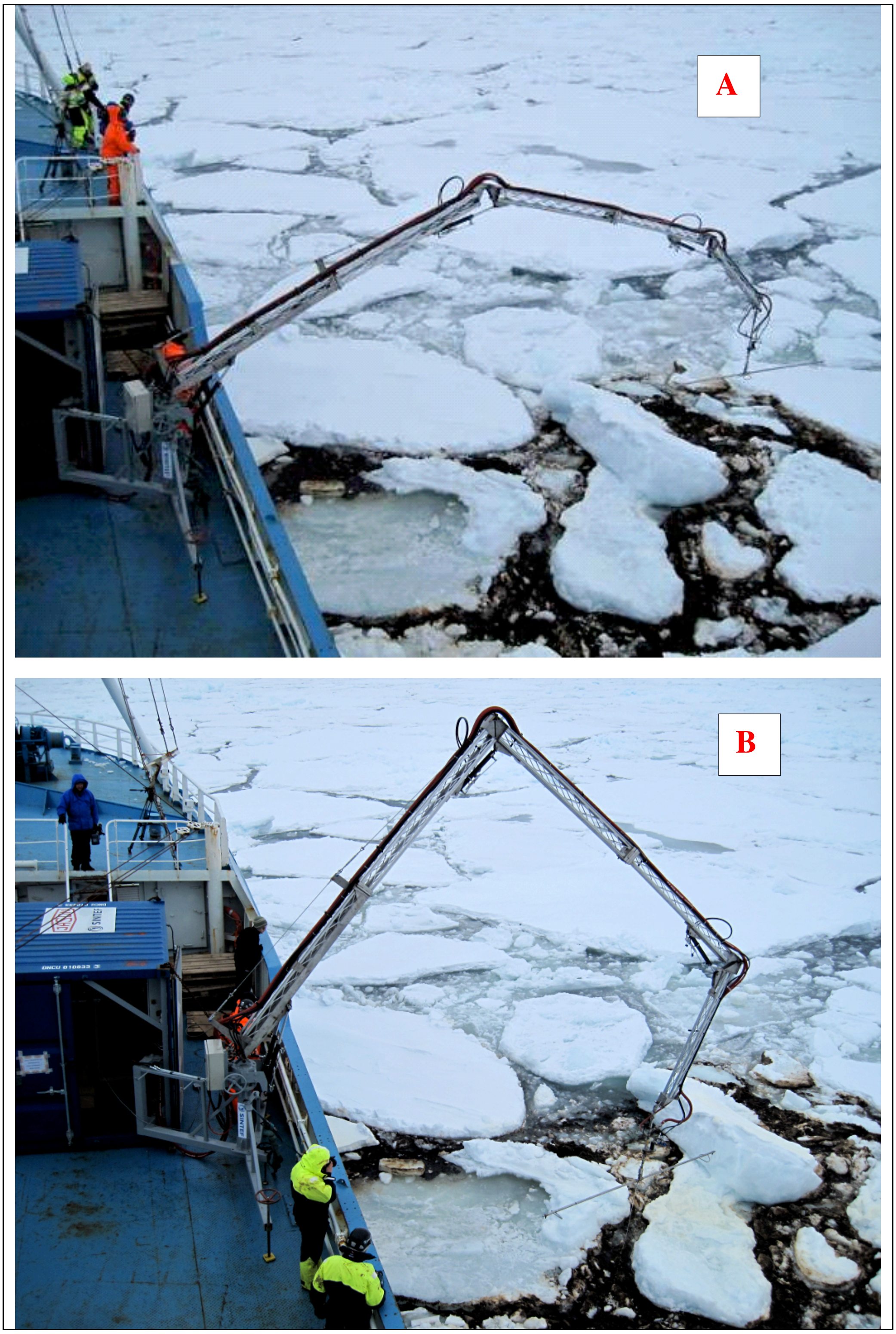

Figure 4: Dispersant application during the field trial in the Barents Sea using the maneuverable spray arm.

MAIN FINDINGS / SUMMARY

The main findings from the dispersant–related tasks of this "Oil in ice" JIP program are given below. Details are given in open technical reports (Brandvik et. al. 2010A and B, Daling et al, 2010 A and B):

- Laboratory and field experiments have verified that oil spilled in ice-covered waters can be highly dispersible by use of oil spill dispersants. The "dispersibility" depends highly on the physico-chemical properties of the oil types and the ice coverage. Use of dispersants on very waxy crude oils seems to have a low potential in ice-covered area.
- The test studies in the SINTEF flume basin have demonstrated clearly that the weathering processes is slowed down when ice is present, enabling a longer "time window" for dispersant application. Some oils spilled in ice may remain dispersible over a period of several days
- Due to the wave damping in high ice coverage, the natural turbulence available to cause dispersion can become a limiting factor. In such situations, use of artificial energy after the dispersant application is important in order to fulfill the dispersion process
- Further refinements of the SINTEF Oil Weathering Model enable to obtain reliable predictions of the "operational time window" for use of oil spill dispersants on the different oils under various ice conditions
- The potential for use of dispersants in ice were further verified during large-scale field trials, where new methodologies and strategies for dispersion of oil in high (80 – 90 %) ice coverage with dynamic currents and ice drift conditions were tested. This included:
    - A new, flexible and maneuverable dispersant spray unit developed through this research program demonstrated its ability to conduct precise application on the oil, avoiding wind-induced drift and reduction in the loss of dispersant applied over the ice floes
    - After allowing the dispersant to soak into the dispersant-treated oil, energy / turbulence supplied by propeller washing and MOB boat water jets was used to complete the dispersion process into very small oil

droplets proved to be highly efficient

Based on these findings, some follow-up studies are recommended:

- A better documentation of the fate of chemically dispersed oil in ice including:
    - spreading and dilution in the water column under the ice
    - interactions between oil droplets and various ice / ice topography
    - degradation of oil droplets under / in ice
    - potential toxicity effects of dispersed oil droplets on arctic / ice fauna
    - potential for use of dispersants in more coastal water / sediment interaction
    - further refinements of numerical 3D spreading model tools
- Further operational improvements / technology development:
    - optimising oil spill dispersant formulations customized for specific oils in cold conditions
    - increasing the capacity and dimensions of the technology for dispersant application in ice-covered area

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