Subsea Dispersant Injection (SSDI) - a New Bench-Scale Laboratory Method for Dispersant Effectiveness Testing

Per Johan Brandvik, Per S. Daling, Frode Leirvik, Øistein Johansen, Emlyn Davies and Daniel F. Krause
SINTEF Materials and Chemistry, NO-7465 Trondheim, NORWAY

Abstract

The main objective for this study was to develop a protocol for bench-top effectiveness testing of subsea dispersants injection (SSDI). The dispersant effectiveness is quantified as a shift in oil droplet size distribution for the chemically dispersed oil compared to the untreated oil.

The new test method is designed for continuous monitoring of an oil plume generated by a turbulent jet. Shift in droplet sizes are monitored as a function of turbulence levels, injection techniques and different dispersant dosage. The capabilities of this new bench-scale method is documented in the original project report by testing a selection of three commercial dispersant products with four different oil types, two turbulence levels, two injection techniques and three dispersant dosages.

The new test protocol is also documented by comparing results with large-scale testing in the SINTEF TowerBasin (6 m high containing 42 000 litres of natural sea water) with the same oil types and dispersants.

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<u>See the full IPIECA-OGP report for further details:</u>
Per Johan Brandvik, Per S. Daling, Frode Leirvik, Øistein Johansen, Emlyn Davies and Daniel F. Krause.. 2014: Subsea Dispersant Effectiveness Bench-Scale Test Protocol Development and Documentation SINTEF report no: A26541. Trondheim Norway 2014. ISBN: 9788214057539.

This report covers SINTEF's part of a comparative study performed both at CEDRE and SINTEF.

Contact person: Per Johan Brandvik, Dr.Scient., Senior Scientist/Professor
SINTEF Materials & Chemistry, Environmental Technology, 7045 Trondheim, Norway.
Email: per.brandvik@sintef.no. Phone: +47 9095 8576

1 Introduction

The size distribution of oil droplets in subsea oil and gas blowouts is known to have strong impact on the subsequent fate of the oil in the environment. Large droplets will rise relatively rapidly and come to the surface relatively close to the discharge location, while small droplets will rise more slowly and can be transported long distances from the discharge location with ambient currents before reaching the sea surface. The smallest droplets may even be kept suspended in the water masses for prolonged periods by vertical oceanic turbulent mixing, and this mechanism is the main rational for application of chemical dispersants.

Subsea injection of dispersants will change the droplet size distribution of the oil due to lowering of the interfacial tension between oil and water. This could strongly affect the fate and effect of the oil from an accidental subsea release.

Testing dispersant effectiveness for subsea injection is very different compared to screening dispersants for surface oil spills. Changes in physical properties of surface oil slicks due to weathering (e.g. increased viscosity due to emulsification) are important for the effectiveness of dispersant applied on traditional surface oil slicks. The sea state is also important, since the dispersion process, in most cases, demands a certain energy (breaking waves). Screening testing of dispersants for surface application is for this reason usually done with artificially weathered oils and a relevant turbulence level. The different standard test methods, IFP, MNS, WSL, Swirling flask and others can be regarded as representatives of different sea surface turbulence levels (sea states).

For SSDI, the situation is, however, very different. The dispersant is applied directly into a stream of fresh oil usually under very turbulent conditions. The following list summarises important factors for dispersant testing for subsea oil spills:

1. Fresh oil, no weathering effects are relevant.
2. Dispersant is injected direct into the oil immediately before or after release (depending of injection technique used)
3. Effectiveness of the dispersant is measured as a shift in droplet size distribution
4. The "Turbulence level" in the test should reflect varying subsea release rates and release diameters, producing realistic release velocities (1-10 m/s).
5. "Turbulence level" should be variable (release rates/diameters).
6. Release conditions in the test method can be related to large scale basin testing (e.g. SINTEF Tower Basin) and operative field conditions e.g. by using the Ohnesorge vs. Reynolds number diagram.

A realistic test protocol should include dispersant injection into a steady stream of oil and continuous monitoring of the shift in droplet sizes. This should also be possible for a wide range of dispersant to oil ratios (DOR 1:1000 – 1:25). For this reason, SINTEF has developed a prototype for a new test method that reflects turbulence levels, injection methods and quantification of effectiveness that are relevant for SSDI. This approach called the SINTEF MiniTower is a down scaled version of the SINTEF TowerBasin (Brandvik et al., 2013).

2 Experimental

Existing bench-scale dispersant effectiveness test methods are designed to test dispersant for use on surface oil slicks where the turbulence levels reflects various sea states or degree of breaking waves. For this reason, SINTEF suggested a concept for a new test method that reflects turbulence levels, possible injection methods and quantification of effectiveness that is specifically relevant for SSDI. SINTEF had already established a prototype for such a bench-top test before this project was initiated. This concept was used for this IPIECA / OGP project and the principles are presented in Figure 2.1 and Figure 2.2.

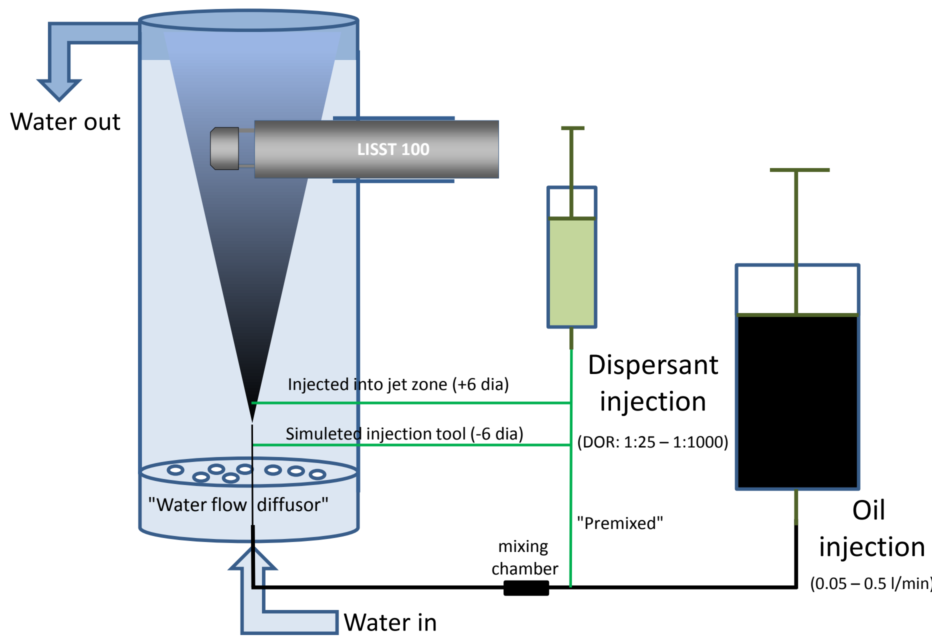

Figure 2.1: Outline of the new subsea Dispersion Injection Effectiveness Test, illustrating the flow through system of natural sea water, injection system of dispersant and release system for oil. The LISST laser scattering system is used for monitoring droplet sizes. Source: SINTEF.

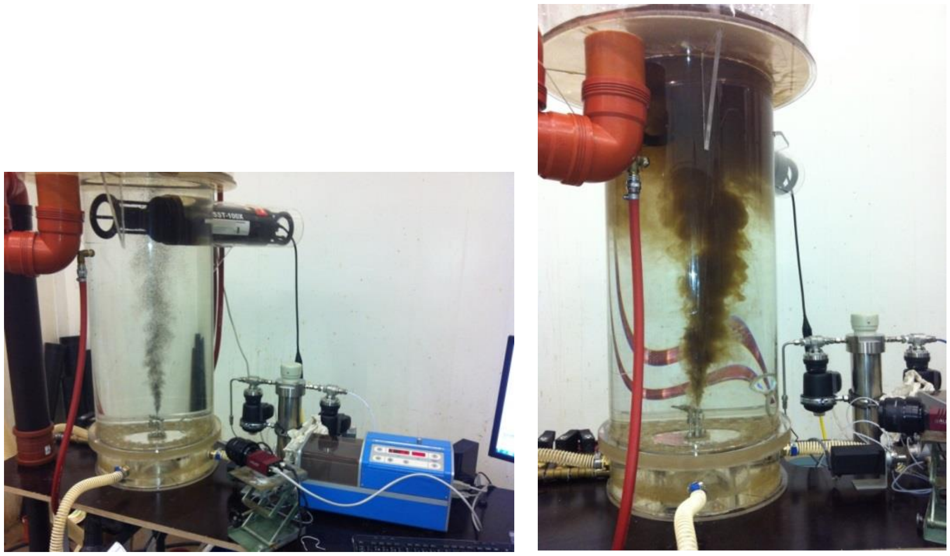

Figure 2.2: Continuous rising plume of untreated Oseberg blend (A) and oil treated with Corexit 9500 DOR 1:100 (B). Dispersant injection syringe pump (blue box) is shown (A).

3 Results

The results from the study are given in the original IPIECA report for details. The main objectives were to screen dispersants, recommend dispersant type, dosage and produce droplet size distributions that can be up-scaled and compared with numbers e.g. from SINTEF DeepBlow plume model

Oil companies operating in Norway have already requested screening studies to rank possible surfactants for subsea injection. SINTEF has used the MiniTower for several such studies (0.5 mm nozzle, 0.1 L/min flow and SIT injection). Figure 3.1 below is an example from a study for Wintershall Norge AS with the Marte Crude oil tested on four different dispersants at 5 different dosages. Figure 3.2 shows that the ranking of the dispersants using SSDI, can give very different compared to the ranking in a "standard" surface effectiveness screening (IFP-test) using a weathered version of the Marte crude.

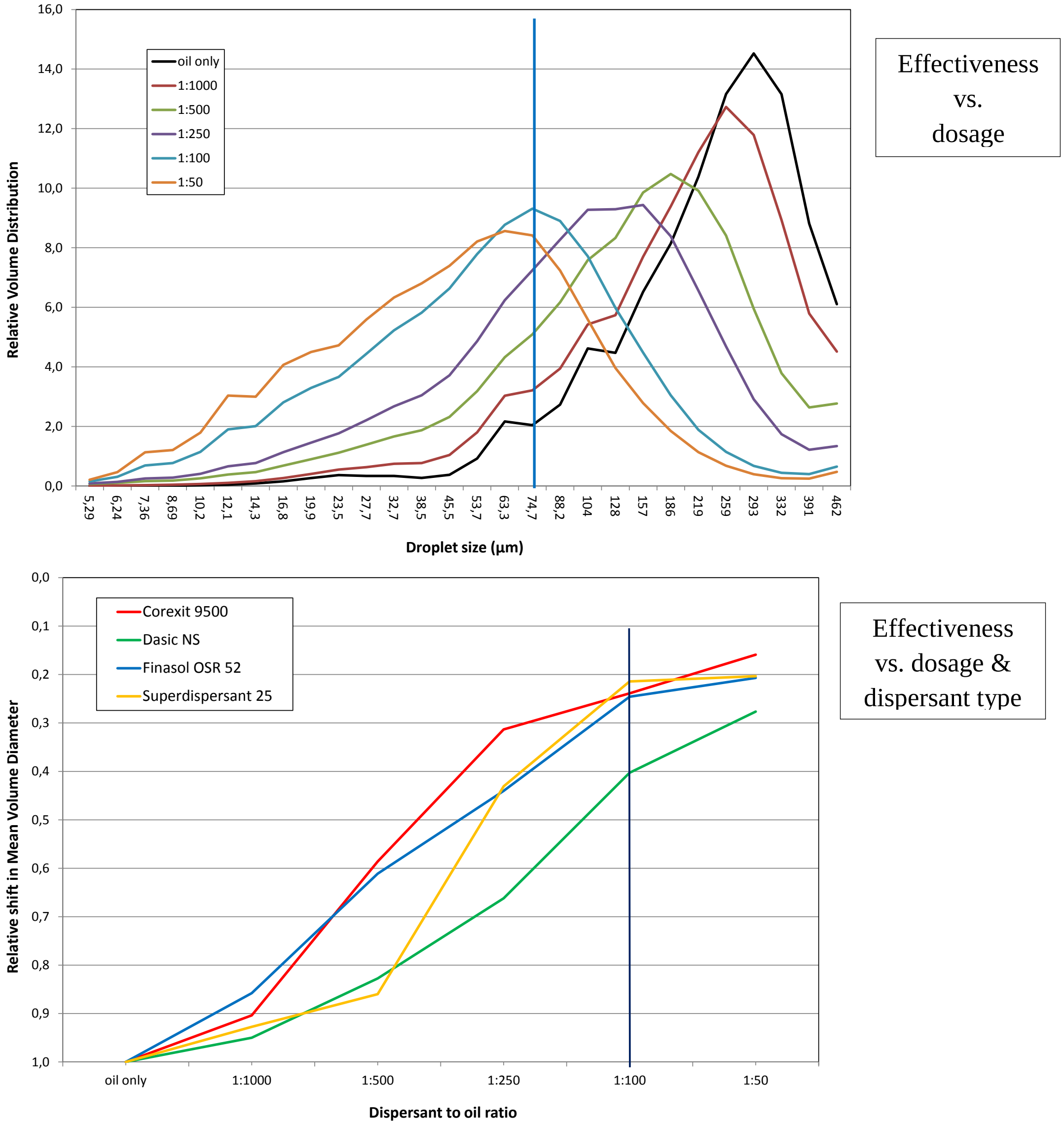

Figure 3.1: Example of screening testing of the Marte oil for Wintershall Norge as a function of DORs (1:1000 - 1:50) with A: Droplet size distribution (volume %) for oil alone and dispersant injection (Finasol OSR 52 and SIT injection). B: Summary of dispersant injection effectiveness for four dispersants presented as relative shift in d_{50} ($1 - (d_{50(reference)} - d_{50(treated\ oil)})/d_{50(reference)}$).

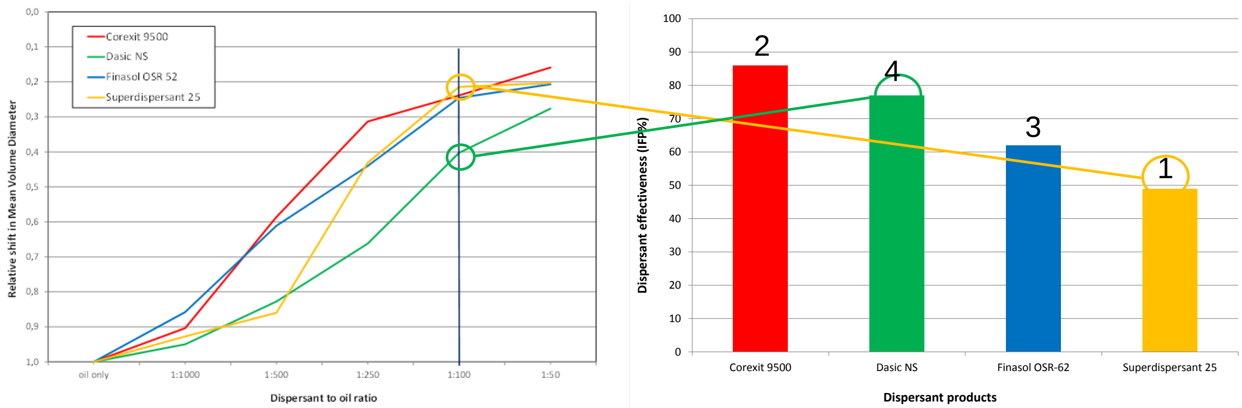

Figure 3.2: Comparison of dispersant ranking from screening testing. A: Subsea injection (MiniTower, SIT injection) and B: Standard dispersant testing for surface application (IFP testing) with the Marte oil for Wintershall Norge.

4 Conclusions

This bench-scale testing is based on down-scaled experiments and the droplet sizes are a function of the experimental conditions (nozzle sizes, flow rates and oil/dispersant properties). Direct interpretations of absolute droplet sizes (larger/smaller than 100 µm etc.) will only be valid for this apparatus and the specific conditions used. However, up-scaling of the obtained droplet sizes to a larger experimental facility (SINTEF Towerbasin) or real field conditions is possible using modified Weber scaling (Johansen et al., 2013).

- A realistic turbulence regime (turbulent jet break up) is important when studying fundamental processes regarding subsea releases of oil.
- The turbulence level must be characterised based on established physical principles, in this case a turbulent jet of oil in water.
- The effectiveness of dispersant injection should be based on the shift in droplets sizes compared to untreated oil (quantified by d_{50})
- Monitoring droplet sizes on a continuous release of oil is important for obtaining statistical significant results.
- A flow-through system of natural sea water enables operating over a large range of optical densities (concentration and droplets sizes).
- Dispersant should be injected in a reproducible and realistic manner into the oil flow as close as possible to the nozzle.
- Dispersant dosage is of large operational importance and can be varied (DOR 1.1000 to 1:25).

5 References

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