Verification of Subsea Dispersant Injection (SSDI) by large-scale effectiveness testing at Ohmsett

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Abstract

Oil droplet- and gas bubbles size distributions formed during oil and gas blowouts are known to have a strong impact on both the fate and the environmental impact of the released oil on the marine environment. Reliable predictions of size distribution in blowouts will thus improve our ability to forecast the fate of oil in the environment, and subsequently provide better guidance for oil spill response operations and relevant information to the public. Multiple experiments studying various aspects of subsea oil releases have been performed earlier in a six-meter high 42 m^3 large Tower Basin in Trondheim, Norway. These projects focused on oil droplet formation, the effect of dispersant dosage and different injection techniques. Related work has also been performed at other basin facilities in Canada, in France in China and in smaller scale at increased pressure in Germany, Australia and in USA.

This presentation focus on droplet data covering a representative size range for large-scale subsea blowouts (0.1 – 12 mm) from large-scale experiments at Ohmsett, the US National Oil Spill Response Test Facility in New Jersey. The generated data is used to verify both SSDI effectiveness and the ability of operative models to predict oil droplet sizes. The presentation will cover the highlight, further details can be found in Brandvik et. al., 2021).

Simulating subsea releases in a basin with a depth of 2.5 meters is not straight forward and to find the preferred experimental design, different releases were simulated with SINTEF's Plume3D model. This modelling led to performing a vertical release while moving the release point horizontally (simulating a horizontal cross current). This increased water entrainment gave sufficient dilution of the oil plume for monitoring the oil droplets, see Figure 1. This was achieved by mounting both the release- and monitoring arrangements on two coordinated moving bridges. Two simultaneous series of oil releases were made during each experiment.
Oil and dispersant flow rates were monitored with inline flow meters, flow rates and other details regarding the experimental set-up can be found in Brandvik et al., 2021.

A broad range of conditions were covered during 10 days of experiments at Ohmsett covering three nozzle sizes (25, 32 and 50 mm), five different flow rates (50 – 300 L/min) with both treated (SSDI) and untreated oil. Alle experiments were performed with a light paraffinic crude (Oseberg blend) consuming totally more than 12 000 litres.

Oil droplet sizes were quantified with SilCam systems developed at SINTEF. In Figure 1 below totally four SilCam systems are indicated, two in each oil plume. Resulting droplet size distributions were based on average reading from the two instruments. Images from the SilCam and examples of size distributions are shown in Figure 2 and 3. More details regarding the concept and use of SilCams can be found in Davies et al., 2017.

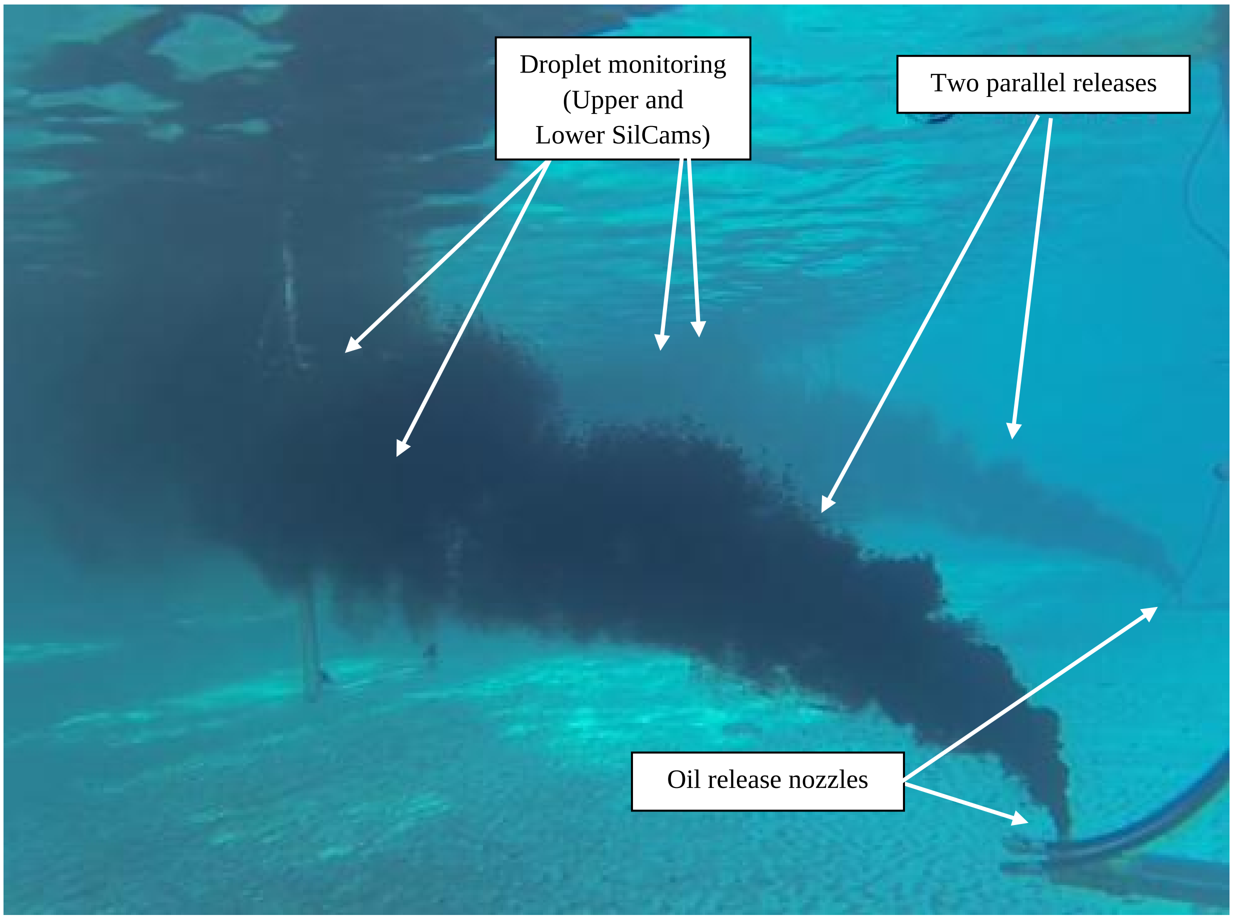

Figure 1: Twin releases of oil from the two different nozzle configurations illustrate plume behaviour and position of monitoring equipment. Two set of SilCams were used to monitor oil droplet sizes in both oil plumes. The closest release arrangement could switch between two different release nozzles (32 mm or 50 mm), the other had a fixed nozzle size (25 mm). From Brandvik et al., 2021.

The measured droplet sizes (averaged) are compared with predicted values in Figure 4 using modified Weber scaling (Johansen et al., 2013). The correlation is high, but some deviation can be observed when the highest oil rates were treated with dispersant (50 mm nozzle, 200 – 400 L/min). The low- and flow rate independent droplet sizes measured are most likely due to oversaturation of the SilCam (too high concentration).

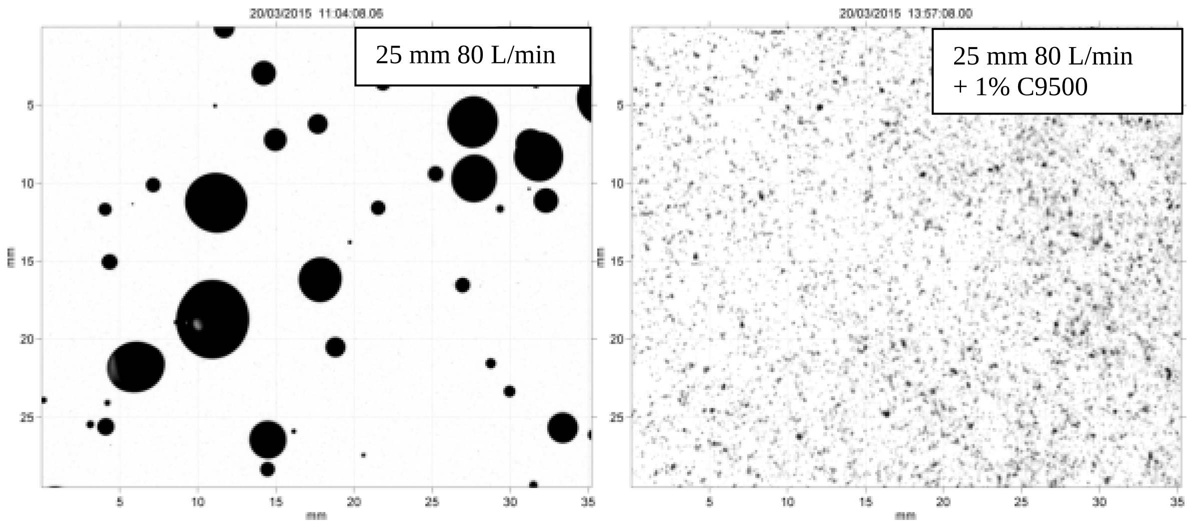

Figure 2: SilCam images showing individual droplets (25 mm nozzle, 80 L/min and 80 L/min with 1% C9500. From Brandvik et al., 2021.

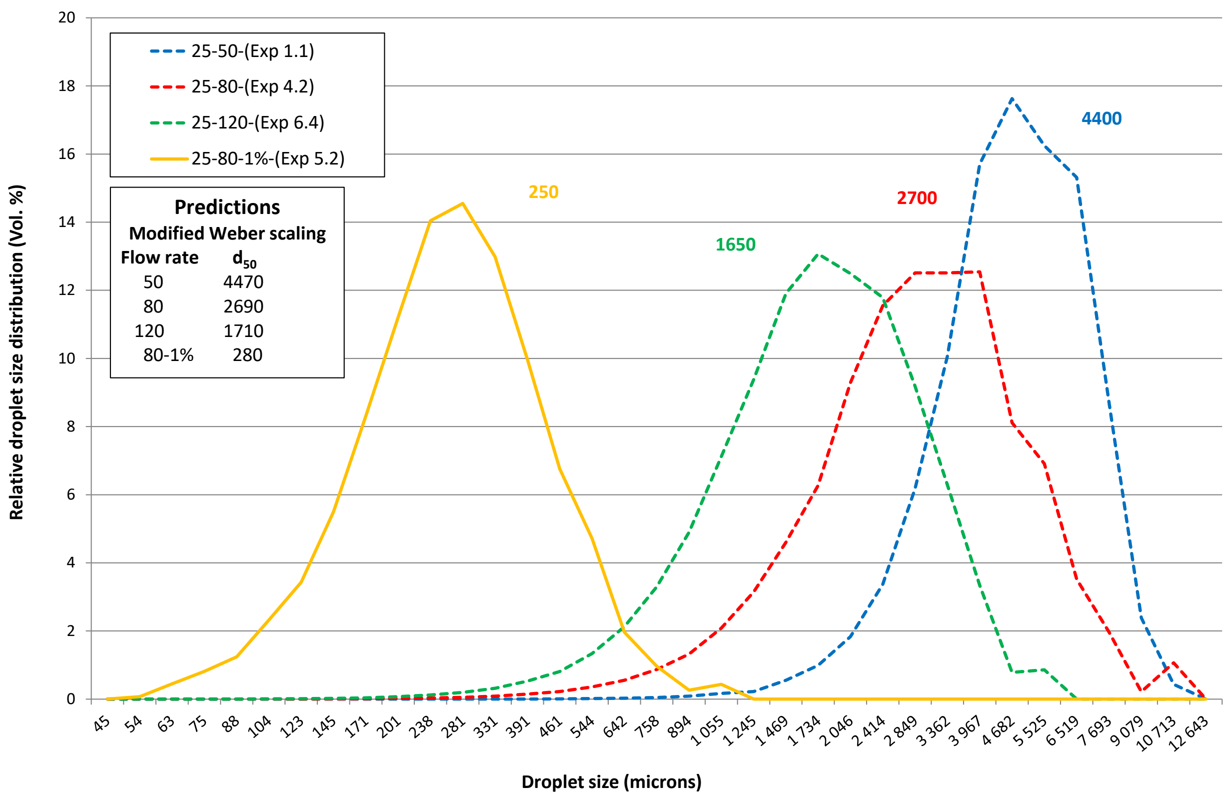

Figure 3: Droplet size distribution (45 - 12 000 µm) from the experiments with the 25 mm nozzle at 50, 80 and 120 L/min and at 50 l/min with 1% Corexit 9500 (simulated injection tool – SIT). Numbers beside graphs are estimated d_{50} from cumulative distribution function (Upper SilCams). Predictions using Modified weber scaling are given in brackets (left). From Brandvik et al., 2021.

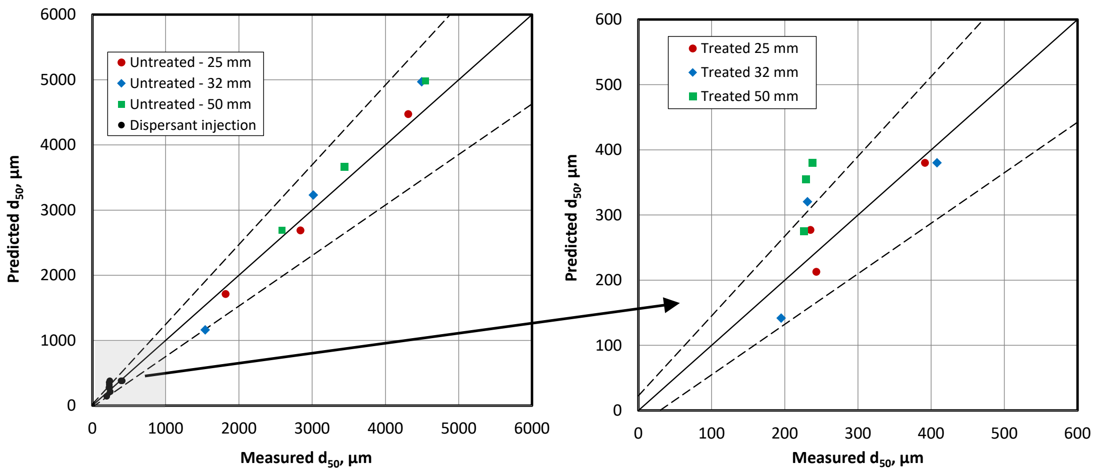

Figure 4: Left figure: All average measured versus predicted oil droplet sizes ($r^2 = 0.95$). Dotted lines indicate ±15% deviation (sample STDev) from a perfect fit (solid line). Left figure contains all averaged samples. Right figure is zoomed in on treated (dispersant injection) samples only (grey rectangle in left figure). From Brandvik et al., 2021.

The experiments show that SSDI will reduce the droplet size by an order of magnitude using a dispersant dosage of 1% (see Figure 3). Since the untreated droplets formed in these experiments were similar in size to those expected in a real-world blowout like Macondo, the study results strongly suggest that SSDI would provide similar performance in the real world.

This new extensive data set fills in the gap between earlier small- and medium-scale studies and the DeepSpill field release in 2000, both with respect to release diameters, oil flow rates and droplet sizes. The data set is also unique with respect to its high number of replicate measurements (3 – 5 replicates for most settings). See Brandvik et al., 2021 for further details.

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