Marine Pollution Bulletin 127 (2018) 175–181

Contents lists available at ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

The sensitivity of the surface oil signature to subsurface dispersant injection and weather conditions

Ragnhild L. Daae*, Jørgen Skancke, Per Johan Brandvik, Liv-Guri Faksness

SINTEF Ocean AS, P.O. box 4762, Torgard, NO-7465 Trondheim, Norway

ARTICLE INFO

Keywords:
Oil spill modelling
Subsea release
Dispersants
Subsea dispersant injection (SSDI)

ABSTRACT

Subsea blowouts have the potential to spread oil across large geographical areas, and subsea dispersant injection (SSDI) is a response option targeted at reducing the impact of a blowout, especially reducing persistent surface oil slicks. Modified Weber scaling was used to predict oil droplet sizes with the OSCAR oil spill model, and to evaluate the surface oil volume and area when using SSDI under different conditions. Generally, SSDI reduces the amount of oil on the surface, and creates wider and thinner surface oil slicks. It was found that the reduction of surface oil area and volume with SSDI was enhanced for higher wind speeds. Overall, given the effect of SSDI on oil volume and weathering, it may be suggested that tar ball formation, requiring thick and weathered oil, could possibly be reduced when SSDI is used.

1. Introduction

Subsea oil development over the course of the past decades has resulted in the drilling of a large number of oil wells on the ocean floor, and technological advances are pushing exploration still further into deeper waters. The major Deepwater Horizon (DWH) and Ixtoc oil spills showed that releases from subsea wells can be large in volume, hard to control, and can lead to extensive environmental damage (Boehm and Fiest, 1982; Fisher et al., 2014; Jernelöv and Lindén, 1981; Ryerson et al., 2012; Valentine et al., 2014). During an oil spill at sea, chemical dispersants are routinely applied to surface oil slicks to reduce the potential for environmental damage, as dispersants facilitate increased oil dispersal under breaking waves (Chapman et al., 2007). In the case of the DWH oil spill, dispersants were additionally injected into the turbulent oil flow as it emerged above the wellhead (Lehr et al., 2010). The purpose of using subsea dispersant injection (SSDI) is to reduce the size of the oil droplets generated in the turbulent oil jet. Smaller droplets rise more slowly, and thereby have greater potential for dispersion, dissolution, and biodegradation, which may reduce the total impact of the oil spill, especially with regard to the fate of the surface slick and subsequent shoreline oiling. For the DWH spill there was not sufficient in situ measurements of the plume to document the effect of SSDI (Kujawinski et al., 2011). However, a theoretical studies of the DWH spill estimated that SSDI reduced the median droplet size from the millimeter range to the sub-millimeter range, which would have greatly increased the rise time and dwell time of the droplets in the water column (Zhao et al., 2015; Testa et al., 2016). Since SSDI has the potential to alter the outcome of a subsea oil spill, it is important to identify the spill characteristics and environmental conditions under which SSDI is an effective response option.

Field experience with SSDI is, fortunately, scarce. On the other hand, much research has recently been done to understand this response option in a laboratory setting. The droplet size reduction that is obtained with SSDI has been extensively characterized in experiments with downscaled blowout models (Brandvik et al., 2013). To transfer these results to the field, Johansen et al. (2013) developed an equilibrium model referred to as modified Weber scaling where dimensionless variables are used to predict droplet sizes. In addition to the data from Brandvik et al. (2013), the modified Weber scaling model was also fitted to data from the DeepSpill experiment, the only large scale experiment performed so far for subsea blowouts (Johansen et al., 2003). SSDI can be simulated in the modified Weber scaling model by reducing the oil-water interfacial tension (Johansen et al., 2013), which although variable between oil types, has been found to decrease by roughly 100 fold for 1% injected dispersant (Brandvik et al., 2013). Another equilibrium droplet size model was developed by Li et al. (2016), who used experimental downscaled blowout and surface entrainment data to fit their model, which could fit data from both blowouts and from breaking waves depending on a scale parameter (Li et al., 2016). The idea behind the equilibrium models is that the droplet size distribution produced by the model should represent the situation after droplet breakup and coalescence have ceased. Others have instead developed dynamic droplet size models, where a time series of droplet breakup and coalescence is calculated with a population balance equation based

* Corresponding author at: SINTEF Ocean AS, NO-7465 Trondheim, Norway.
E-mail address: ragnhild.l.daae@sintef.no (R.L. Daae).

https://doi.org/10.1016/j.marpolbul.2017.11.067
Received 7 July 2017; Received in revised form 28 November 2017; Accepted 30 November 2017
0025-326X/ © 2017 Elsevier Ltd. All rights reserved.

on the blowout jet mixing energy (Nissanka and Yapa, 2016a; Zhao et al., 2014). Although very different in approach, the above-mentioned equilibrium and dynamic models all predict that the DWH spill generated droplets with a size up to several millimeters without SSDI, and on the sub millimeter scale with SSDI (Li et al., 2016; Nissanka and Yapa, 2016b; Testa et al., 2016; Zhao et al., 2014). On the other hand, other authors have argued that blowouts on the scale of the DWH generate droplets that are significantly smaller, between 1 μm and 300 μm (Aman et al., 2015; Paris et al., 2012). These studies derive the droplet size distribution not from a turbulent jet, but from experiments that produce a constant shear that is not representative of the rapidly decreasing shear that droplets would encounter in a blowout (Aman et al., 2015; Boxall et al., 2012). Not surprisingly, the models that predict the initial untreated small droplets found that SSDI did not lead to large differences in the amount of oil reaching the surface (Aman et al., 2015; Paris et al., 2012). Ultimately, experimental deep water subsea releases with large release diameters and SSDI are needed in order to validate the different droplet size models.

The utility of a droplet size model is best achieved when used to set the initial condition of a subsea blowout in an oil spill model. Studies of particle tracking using the small droplets predicted by the stirred cell experiments found that SSDI did not lead to large differences in the amount of oil reaching the surface (Aman et al., 2015; Paris et al., 2012). Another study (Testa et al., 2016), used modified Weber scaling to predict large untreated droplets in order to investigate the effect of SSDI on oil dispersal for the DWH spill. They found that it took longer for the oil to reach the surface when SSDI was applied (8 h vs 4 h), and that the total volume of oil on the surface was greatly reduced when SSDI was applied, as more was retained under water. Focusing on short-term effects, the particle model used by Testa et al. (2016), did not include several processes that are known to affect the fate of oil at sea, such as evaporation, biodegradation, dissolution, emulsion formation, and entrainment of surface oil by breaking waves. These processes, previously reviewed in detail for oil spill modelling, (Afenyo et al., 2016; Reed et al., 1999; Spaulding, 2017, 1988), can have a large effect on the outcome of an investigation of the efficiency of SSDI. One aspect is that smaller oil droplets will be subjected to more rapid biodegradation and dissolution (Brakstad et al., 2015). Furthermore, oil that reaches the surface when SSDI has been applied may form thinner slicks as it surfaces over a larger area, and may therefore be less emulsified after a certain time at sea. In turn, a lower degree of emulsification will affect the extent of dispersion, as emulsified oil is more resistant to natural dispersion by wave action (Johansen et al., 2015). Due to the large impact of surface processes on the fate of an oil spill, it is of interest to investigate the effectiveness of SSDI application using an oil spill model that includes the above-mentioned physical and chemical processes.

The objective of this work was to use a state of the art oil spill model to investigate how SSDI affects the surface signature of oil from a deepwater blowout. Importantly, the aim was in particular to investigate the impact of varying weather conditions, as represented by different wind speed. As exemplified by the DWH spill, weather conditions during an oil spill may alternate between wind-still conditions and hurricane force winds, which greatly affect the moment to moment evolution of the spill (MacDonald et al., 2015).

2. Methods

2.1. The OSCAR oil spill model

The OSCAR model is a three-dimensional Lagrangian oil spill trajectory model for predicting the transport, fate and effects of released oil. The model development is closely linked to laboratory and field activities at SINTEF. OSCAR covers the key physical and chemical processes that affect oil spilled at sea, including evaporation, surface spreading and transport, entrainment into the water column, emulsification, sedimentation and shore interaction (Reed et al., 1995). The varying solubility, volatility, and aquatic toxicity of oil components are accounted for by representing the oil in terms of 25 pseudo-components (Reed et al., 2000). Subsurface oil spills are initialized with a jet and plume model (Johansen, 2000) that uses a Weber-scaling method to calculate droplet sizes based on outlet conditions (Johansen et al., 2013). Oil viscosity during subsea blowouts, which is an important parameter in the Weber-scaling droplet size calculation, is obtained by adjusting the oil viscosity to a temperature found as a function of the released oil temperature and ambient water temperature, using a method described elsewhere (Skancke et al., 2016).

The ocean current data used in this study corresponds to a measured current profile from a location in the Beaufort Sea and has been provided ("ALS", 2013). The average current speed in the modelling period was 7.1 cm/s for the total water column, and 11.7 cm/s for the upper 100 m. The maximum current speed in the upper 100 m was 27.2 cm/s. Temperature and salinity profiles were obtained from the National Virtual Ocean Data System ("World Ocean Atlas, 2005," 2013).

3. Results

3.1. Model setup

The effect of SSDI and the fate of the surface oil slick were investigated during different weather conditions for a deepwater oil blowout. The blowout was set at 700 m, deep enough to ensure a trapping of the plume in the subsurface layer and therefore a sensitivity in the outcome to differences in the initial droplet size distribution. Six simulations were performed, where the two parameters of variation were the wind speed (0, 5 and 10 m/s) and whether SSDI was applied or not (SSDI vs. oil only). To establish a baseline condition of an uninterrupted spill, a 2-day constant release was simulated, and then the oil was tracked for an additional 8 days in order to investigate the evolution of the surface slick after the subsea release was over.

The oil spill simulation parameters for this study are given in Table 1. We have modelled the application of SSDI assuming that an injection of 1% dispersant reduces the interfacial tension between oil and water by a factor of approximate 100, as supported by experimental data (Brandvik et al., 2013). For comparison, the average dispersant to oil ratio during the SSDI during the Deepwater Horizon blowout was estimated to 0.5%, lower than was is recognized as to achieve maximum effect (Lehr et al., 2010).

Oseberg Blend is a light paraffinic crude with a low asphaltene and wax content (0.2 & 2.7 wt%). Such a low viscosity oil would is highly relevant for a high flow rate scenario like this. Further details regarding oil properties are given in Brandvik et al., 2013.

With the given release parameters (Table 1), oil treated with SSDI reduced the median droplet size by 90%, from 3.69 mm to 0.434 mm.

Table 1
Simulation parameters.

Parameter	Value
Release depths	700 m
Surface wind	0, 5 and 10 m/s (constant)
Duration of simulation	10 days
Oil type	Oseberg Blend
Oil density	0.839 (kg/l)
Release location	Beaufort Sea
Release rate	7000 t/day (52,478 barrels/day)
Duration of release	2 days
Temperature of release	60 °C
Droplet formation temperature	33.2 °C (Skancke et al., 2016)
Oil viscosity at droplet formation	3.9 cP
Release diameter	0.25 m
Gas-to-oil Ratio (GOR)	100 at standard conditions (1 atm)
Gas density	0.8 kg/Sm^3

Download English Version:

https://daneshyari.com/en/article/8871630

Download Persian Version:

https://daneshyari.com/article/8871630

Daneshyari.com