Coastal Response Research Center

THIS DRAFT IS FOR PUBLIC INPUT ONLY
(JANUARY 22, 2016 - FEBRUARY 22, 2016, 5:00 PM ET)

State-of-Science for Dispersant Use in Arctic Waters

Efficacy and Effectiveness

I. General Overarching Statements Concerning Dispersant Efficacy and Effectiveness

Knowns:

1. Based on studies to date, statements in this document are generally true, but we must consider that there are exceptions with certain oils because the environment, oil, and water systems are very complex.
2. For this document, Arctic waters were defined by the types of ice considered:
   - Ice-free water;
   - Ice-infested waters; and
   - Full cover.

II. Environmental Factors that Impact Dispersant Effectiveness

A. General Considerations

Knowns:

1. Overall the major factors affecting dispersant effectiveness are:
   - Oil type, especially as it relates to viscosity of the initial oil or as a result of weathering or lower temperatures;
   - Emulsification;
   - Mixing energy (magnitude, duration and intensity of shear);
   - Dispersant formulation;
   - Dose rate;
   - Water salinity (ranging from freshwater to seawater up to 35 ppt). (Nedwed et al., 2014; Belk et al., 1989);
   - Potential for dilution (e.g., small, shallow contained bodies of water, such as tidal pools vs. open ocean, where there is potential for infinite dilution); and

- Temperature.

2. Oil that is readily dispersed in temperate and warmer regions is expected to remain dispersible in colder regions, provided that the temperature is warm enough to allow oil to remain as a fluid.

Uncertainties:

1. The complexity derived from the variables listed above defies definition of a clear problem statement, confounding the acceptance of universal conclusions. There are too many caveats to every study (and many are not declared).
2. The environment, oil, and water systems are very complex, so there are uncertainties that exist; therefore we may have to be mindful about transferring the general rules of thumb about dispersibility to the Arctic, especially in the presence of ice.
3. We need to be aware of the areas of confidence (e.g., low viscosity oils have been shown to be highly dispersible at freezing temperatures) and the areas of uncertainty.

III. Individual Factors

A. Temperature

Knowns:

1. Temperature alters the physical properties of oil and influences the effectiveness of dispersion. It is the physical properties that primarily impose the limitations to the dispersibility of the oil in water (Mukherjee et al., 2011).
2. There are low-medium viscosity oils (less than 1,000-2,000 centipoise) that are readily dispersible in seawater at freezing temperatures.
3. Based on laboratory studies, crude and fuel oils that effectively disperse at warmer temperatures are expected to disperse at near freezing temperatures as long as they remain fluid (pour point is not necessarily an indicator of fluidity).

Uncertainties:

1. Uncertainties arise as to the dispersibility of oils of higher viscosity.

B. Mixing Energy

Knowns:

1. Ice-Free Water
   - Mixing energy required to disperse dispersant-treated oil is a function of oil properties, dispersant type, degree of weathering/emulsification, salinity, and dispersant to oil ratio (DOR).

- The mixing energy available in Arctic ice-free water is equivalent to mixing energy in temperate water.

2. Ice-Infested Waters
   - The presence of ice dampens surface wave energy, slowing the kinetics of the dispersion process.
   - The shearing caused by the motion of small pieces of ice in non-breaking waves may enhance dispersion by providing additional near surface mixing energy that would otherwise not be present in the absence of ice.
3. Propeller (Prop) Wash
   - Prop wash provides additional energy to enable dispersion of dispersant-treated oil in ice-free, ice-infested, and full ice cover waters (broken by an ice breaker) when available mixing energy is insufficient (Spring et al., 2006; Nedwed et al., 2007).
4. Stability
   - Dispersants have the capacity to enhance the transfer of a slick of petroleum oil from the water/air interface (surface) down into the water column, producing a higher concentration of smaller oil droplets that have greater stability than would occur naturally.
   - Even though the surfactants may leach from the droplets, the likelihood of coalescence and resurfacing of smaller droplets to form a slick is very small because of the dilution potential in the open ocean and the continuous presence of turbulence in the water column.
   - Larger droplets remain prone to re-surfacing (Li et al., 2011)

Uncertainties:

1. The effects of different forms of ice, such as brash or frazil ice have not been studied with respect to surface mixing energy.
2. The effectiveness of oil dispersion is not fully characterized under concentrated ice-infested waters.
3. The effect of the presence of ice on the interplay between shearing caused by the motion of small pieces of ice in non-breaking waves, the dampening of wave energy needed for dispersion, and reduced weathering on the window of opportunity is not fully characterized.

IV. Limitations to the Understanding of Dispersant Effectiveness

Knowns:

1. General Effectiveness
   - Dispersant effectiveness varies between laboratory test methods due to different conditions and analytical techniques, (Clark et al., 2005) and is not expected to be equivalent to field conditions. These tests are used for screening of dispersants and oils, conducting physical studies, developing new dispersants, or broadly informing field effectiveness potential.
2. Formulations
   - In the U.S., the core understanding of dispersant use and effectiveness is based upon Corexit 9500/9527.
   - Studies indicate the potential for new formulations to improve dispersant effectiveness, such as a new gel formulation. Such new formulations are not commercially available for testing (Nedwed, 2010; Vandamme et al., 2012).
3. Subsea Application
   - Scale testing at 10°-12°C and low pressure (1-2 atmospheres) (Nedwed, 2014), indicates there is a significant reduction in droplet size distribution when dispersants are added at the point of turbulent subsurface release.

Uncertainties:

1. General Effectiveness
   - While some of the major environmental factors affecting dispersant effectiveness have been well studied, the influences of other variables have not. For example, the general trends for low salinity and hyper-saline waters and oils with viscosities above 2000 centipoise are less well known.
2. Formulations
   - The degree of dispersion effectiveness for non-Corexit dispersants over a broad range of oils and environmental conditions has been less studied and therefore is uncertain.
3. Subsea Application
   - The degree to which the presence of associated gas at high pressure alters the effectiveness of subsea dispersion is uncertain.

Point(s) of Disagreement:

1. There is no agreement on the influence of wax (long chain paraffin), resin, and asphaltene content as major limiting factors on effective dispersion independent of viscosity.

V. Detection and Monitoring of Effectiveness in the Field

Knowns:

1. Protocols exist for monitoring dispersant effectiveness in ice-free surface waters (i.e., SMART, 2006; API 2013; Parscal et al., 2014, NRT Atypical Guidance Document). There are no studies that document the monitoring approach of dispersant effectiveness in ice-infested surface waters or under ice. While dispersion effectiveness in ice during a field trial has been estimated, the monitoring methods and criteria used were not described (Sørstrøm et al., 2009).
2. The existing monitoring techniques for estimating dispersant effectiveness are visual observation at the surface (e.g., an observed decreased in slick size), fluorescence and particle size monitoring for the water column (Li et al., 2011), and supporting monitoring data on hydrography (temperature, salinity), pH, DO, turbidity (SMART protocol document).
3. There are some new techniques that have and are being developed that provide the ability to measure specific compounds (e.g., in-situ mass spectrometry) and are useful in quantifying oil in the water (Reddy et al., 2011)

Uncertainties:

1. Quantitative assessment techniques for measuring overall effectiveness currently have a broad range of uncertainty.

References Cited:

API. 2013. Industry Recommended Subsea Dispersant Monitoring Plan Version 1.0 API TECHNICAL REPORT 1152 September 2013. *American Petroleum Institute*. 10pp.

Belk J.L., Elliott D.J., and Flaherty L.M. 1989. The comparative effectiveness of dispersants in fresh and low salinity waters. *International Oil Spill Conference Proceedings*. Vol. 1989, No. 1 (February 1989) pp. 333-336.

Clark J., Becker K., Venosa A., and Lewis A. 2005. Assessing Dispersant Effectiveness For Heavy Fuel Oils Using Small-Scale Laboratory Tests. *International Oil Spill Conference Proceedings*. Vol. 2005, No. 1 (May 2005) pp. 59-63.

Li Z., Lee K., King T., Niu H., and 2 other authors. 2011. Application of Entropy Analysis of in Situ Droplet-size Spectra in Evaluation of Oil Chemical Dispersion Efficacy. *Marine Pollution Bulletin*. 62(10): 2129-2136.

Mukherjee B., Turner J., and Wrenn B.A. 2011. Effect of Oil Composition on Chemical Dispersion of Crude Oil. *Environmental Engineering Science*. 28(7): 497-506.

Nedwed T.J., Belore R., Spring W., and Blanchet D. 2007. Basin-scale Testing of ASD Icebreaker Enhanced Chemical Dispersion of Oil Spills. *Arctic and Marine Oilspill Program Proceedings*. 1: 151-160.

Nedwed T.J., Clark, J.R., Canevari G.P., and Belore R. 2008. New Dispersant Delivered As A Gel. 2008 *International Oil Spill Conference Proceedings*. Vol. 2008, No. 1 (May 2008) pp. 121-125.

Nedwed T.J., 2010. New Dispersant Gel Treats Marine Oil Spills more Effectively with Less Product. *Society of Petroleum Engineers*, Conference on Health, Safety and Environment in Oil and Gas Exploration and Production in Rio de Janeiro, Brazil. April 2010.

Nedwed T.J., Ghurye G.L., Tidwell A.C., and Canevari G.P. 2014. Effect of Salinity and Viscosity on Crude Oil Dispersion. *Arctic and Marine Oilspill Program Proceedings*. Vol 2014, pp. 610-616.

Nedwed T.J., 2014. Overview of American Petroleum Institute (API) Joint Industry Task Force Subsea Dispersant Injection Project. 2014 *International Oil Spill Conference Proceedings*. May 2014, Vol. 2014, No. 1 pp. 252-265

Parscal B., Young R., and Barone R. 2014. Modernization of Special Monitoring of Applied Response Technologies (SMART) Technology and Methods – 2014. United States Coast Guard, Acquisition Directorate, and Research & Development Center. Report No. CG-D-08-14. 34pp.

Reddy C.M., Arey J.S., Seewald J.S., Sylva S.P., and 8 other authors. 2012. Composition and fate of gas and oil released to the water column during the Deepwater Horizon oil spill. Proceedings of the National Academy of Sciences. 109(50): 20229-20234.

SMART. 2006. Special Monitoring of Applied Response Technologies. U.S. Coast Guard, National Oceanic and Atmospheric Administration, U.S. Environmental Protection Agency, Centers for Disease Control and Prevention, Minerals Management Agency. 43pp.

Sørstrøm S.E. 2009. Full-scale field experiment. Cruise report. May 9-25, 2007. SINTEF Report No 25. 20pp.

Spring W., Nedwed T., and Belore R. 2006. Icebreaker Enhanced Chemical Dispersion of Oil Spills. *Proceedings of the Twenty-ninth Arctic and Marine Oilspill Program (AMOP) Technical Seminar*. Environmental Canada, Ottawa, ON. 711-727.

<u>The panel consisted of:</u>

Catherine Berg, NOAA Scientific Support Coordinator, Office of Response and Restoration--Emergency Response Division
Robyn Conmy, Ph.D., Research Ecologist, NRMRL/LRPCD, U.S. Environmental Protection Agency
Ben Fieldhouse, Emergencies Science and Technology Section, Environment Canada
Merv Fingas, Ph.D., Spill Science
Tim Nedwed, Ph.D., Oil Spill Response Senior Technical Professional Advisor, ExxonMobil Upstream Research Company
Christopher Reddy, Ph.D., Woods Hole Oceanographic Institution
Ken Trudel, Ph.D., SL Ross Environmental Research Ltd
Tim Steffek, Oil Spill Preparedness Division, Bureau of Safety & Environmental Enforcement

NOAA ORR Leads for this project: Doug Helton and Gary Shigenaka
USEPA Leads for this project: Vanessa Principe and Greg Wilson

Facilitator: Nancy E. Kinner, Ph.D., UNH director, Coastal Response Research Center, University of New Hampshire

Disclaimer - This "State-of-Science on Dispersant Use in Arctic Waters: Efficacy and Effectiveness" document presents a compilation of individual opinions of the participants in this session of the State-of-Science for Dispersant Use in Arctic Waters initiative. To the extent that the Federal Government requested certain information, it did so on a purely individual basis. Similarly, the information herein was presented to the Federal Government by individual participants and represent the participants' individual views and policies. Therefore, the statements, positions, and research opinions contained in this document do not reflect any consensus on the part of any of the participants and may not necessarily reflect the views or policies of any individual federal department or agency, including any component of a department or agency that participated in developing this document. No federal endorsement should be inferred.