Understanding Oil Spill Dispersants: Efficacy and Effects

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Dispersant Use in the U.S.

- RRTs have established "pre-approval" zones in most offshore areas
- Dispersants used 8x in U.S., 7x in GOM since 1999
- Proposed USCG rules will require ability to apply dispersants within 12 hours in all pre-approval zones
- Availability of dispersant application resources will likely lead to consideration in nearshore areas
- RRTs have been conducting Ecological Risk Assessment Workshops to discuss dispersant use in nearshore areas

SPONSORS

- Minerals Management Service, DOI
- National Oceanic and Atmospheric Administration
- American Petroleum Institute
- U.S. Coast Guard

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STATEMENT OF TASK

1. **Review and evaluate ongoing research and existing literature on dispersant use (including international studies) with emphasis on:**

   a) factors controlling dispersant effectiveness (e.g., environmental conditions, dispersant application vehicles and strategies, and oil properties, particularly as the oil weathers),

   b) the short- and long-term fate of chemically or naturally dispersed oil, and

   c) the toxicological effects of chemically and naturally dispersed oil

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STATEMENT OF TASK (cont.)

2. **Evaluate the adequacy of the existing information about dispersants to support risk-based decisionmaking regarding response options for a variety of spatially and temporally defined oil spills**

3. **Recommend steps that should be taken to fill existing knowledge gaps. Emphasis will be placed on how laboratory and mesoscale experiments could inform potential controlled field trials and what experimental methods are most appropriate for such tests**

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Primary Finding

In general, the information base used by decisionmakers dealing with spills in areas where the consequences of dispersant use are fairly straightforward (e.g., situations where rapid dilution has the potential to reduce the possible risk to sensitive populations or habitat) **has been adequate.**

Thus,

Primary focus of this report is on supporting decisions involving trade offs among sensitive species or habitats in **nearshore settings.**

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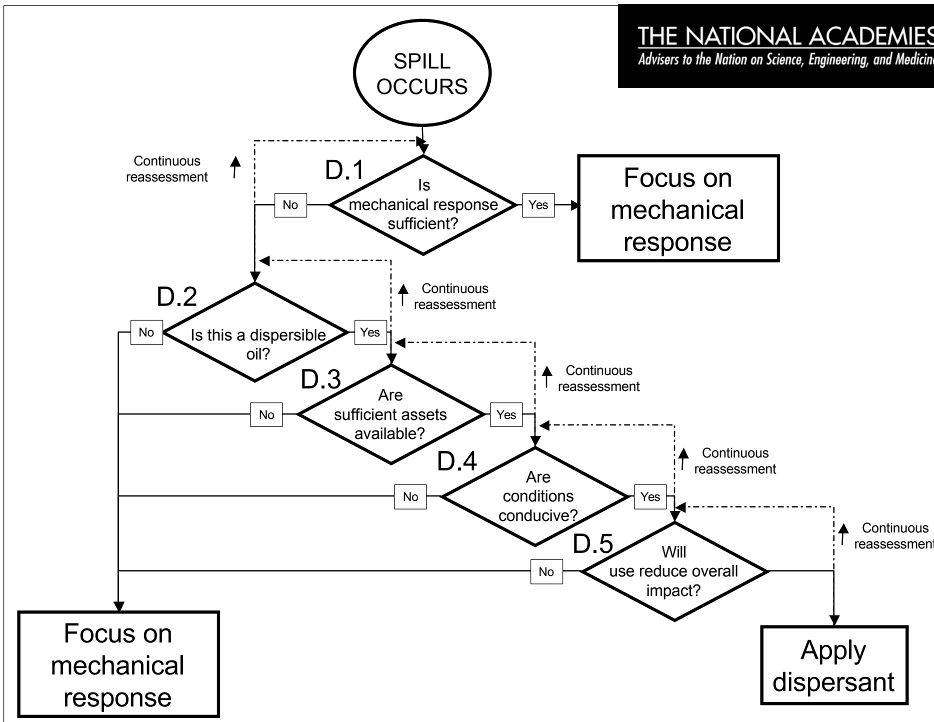

Report Recommendations
D.1 WILL MECHANICAL RESPONSE BE SUFFICIENT?

Given that the use of dispersants does not remove oil from the environment, dispersant use is only considered when the answer to this question is "no," which then leads decision makers to evaluate the appropriateness of dispersant use.

- Too far from shore for safe/effective mechanical response
- Sea conditions exceed operational limits of vessels/skimmers
- Sensitive resources in path of oil trajectory

Requires good trajectory analysis to predict future locations of the slick

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Report Recommendations
D.2 IS THE SPILLED OIL OR REFINED PRODUCT KNOWN TO BE DISPERSIBLE?

Identify the mechanisms and rates of oil weathering processes that control the chemical effectiveness of dispersants (bench-scale and wave-tank tests). Because of the limited funds and costs of wave-tank experiments, it is especially essential that wave-tank studies be well-coordinated.

- Measure key parameters (e.g., energy input, droplet-size distributions)
- Effectiveness on weathered emulsions is important
- Accepted standards of experimental design
- Objective is to determine relationship between energy dissipation rates and chemical effectiveness for a range of oil viscosities and weathering states

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Report Recommendations
D.2 IS THE SPILLED OIL OR REFINED PRODUCT KNOWN TO BE DISPERSIBLE?

Coalescence and resurfacing of dispersed oil droplets as a function of mixing time should be studied in flumes or wave tanks with high water-to-oil ratios (to promote leaching of surfactant into the water column).

- Surfactant leaching may reduce effectiveness of oil dispersion and increase droplet coalescence

The concentration of oil should be measured in all identifiable compartments to which it could be transferred when dispersant effectiveness is investigated in wave tanks.

- Mass balances are difficult and seldom attempted
- Key to better understand the accuracy of effectiveness quantification

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Report Recommendations
D.3 ARE SUFFICIENT CHEMICAL RESPONSE ASSETS (I.E., DISPERSANT, EQUIPMENT AND TRAINED PERSONNEL) AVAILABLE TO TREAT THE SPILL?

If and when dispersant application capabilities are required, it will be necessary to implement methods and procedures to ensure the readiness of response equipment and supplies for dispersant use, similar to the requirements for mechanical response equipment.

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Report Recommendations
D.4 ARE THE ENVIRONMENTAL CONDITIONS CONDUCIVE TO THE SUCCESSFUL APPLICATION OF DISPERSANT AND ITS EFFECTIVENESS?

Develop a research program that provides the data needed to predict, through modeling of the chemical, environmental, and operational conditions, the overall effectiveness of a dispersant application, specifically considering conditions representative of nearshore physical settings.

- Models provide quantitative predictions of tradeoffs with/without dispersants
- Use in pre-planning and emergency response
- Effectiveness currently an input value
- Complex combination of chemical, operational, and hydrodynamic factors
- Need ability to predict effectiveness over time using physical-chemical models (determine the window of opportunity)
- Key consideration in tradeoff analyses

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Report Recommendations
D.4 ARE THE ENVIRONMENTAL CONDITIONS CONDUCIVE?

Experimental systems used for bench-scale effectiveness tests should be characterized to determine the energy dissipation rates that prevail over a wide range of operating conditions. Future effectiveness tests should measure chemical effectiveness over a range of energy dissipation rates to characterize the functional relationship between these variables. Finally, evaluation of chemical effectiveness should always include measurement of the droplet-size distribution of the dispersed oil.

- Energy dissipation rate is the most important hydrodynamic factor in predicting dispersion
- It varies widely among experimental systems but is seldom measured
- Droplet-size distributions in experimental systems are needed to identify mechanisms and compare them to those observed at sea

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Report Recommendations
D.4 ARE THE ENVIRONMENTAL CONDITIONS CONDUCIVE?

The design of wave-tank dispersant-effectiveness studies should specifically test hypotheses regarding factors that can affect operational effectiveness.

- Wave-tanks tests are more realistic - mechanism of energy input and droplet formation

- Operational factors to consider:
  - water-in-oil emulsification
  - formation of a "skin" that resists dispersant penetration
  - dispersant droplet size and impact velocities
  - range of energy-dissipation rates

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Report Recommendations
D.4 ARE THE ENVIRONMENTAL CONDITIONS CONDUCIVE?

Develop a coordinated program to obtain needed information about turbulence regimes at a variety of interrelated scales.

- To correlate lab-scale and mesocosm experiments with open-ocean conditions - need understanding of the turbulence regime in all three
- Biggest uncertainty in computer models is appropriate horizontal and vertical diffusivities
- Growing availability of OOS in coastal waters will improve real-time modeling applications

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Report Recommendations
D.4 ARE THE ENVIRONMENTAL CONDITIONS CONDUCIVE?

Future field-scale work, if deemed necessary, should be based on the systematic and coordinated bench-scale and wave-tank testing recommended in the report.

Field studies benefits:
- best representation of reality
- best for operational effectiveness
- only way to measure hydrodynamic effectiveness
- can test relationships that affect dispersant effectiveness
- useful for model calibration

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Report Recommendations
D.4 ARE THE ENVIRONMENTAL CONDITIONS CONDUCIVE?

Field studies weaknesses:

- expensive so have limited scope and duration, no replication
- limited data set from any one trial, reflects only test conditions
- cannot control weather, physical conditions
- field measurements are more difficult
- operational effectiveness may be higher than "real" spills

Difficult to envision the proper role of field testing where researchers have yet to reach consensus on standard protocols for wave tank tests

Report Recommendations
D.4 ARE THE ENVIRONMENTAL CONDITIONS CONDUCIVE?

Tank tests that determine the ability of mechanical recovery methods to recover oil that has been treated with dispersant but not effectively dispersed, or re-floated oil, should be carried out.

- Dispersants are seldom 100% effective initially and eventually become ineffective as the oil weathers
- Would address concern that use of dispersants would reduce later efforts at mechanical recovery

Report Recommendations
D.5 WILL THE EFFECTIVE USE OF DISPERSANTS REDUCE IMPACTS TO SHORELINE AND WATER-SURFACE RESOURCES WITHOUT SIGNIFICANTLY INCREASING IMPACTS TO WATER-COLUMN AND BENTHIC RESOURCES?

Oil trajectory and fate models used to predict the behavior of dispersed oil should be improved, verified, and then validated in an appropriately designed experimental setting or during an actual spill. Meet the needs of both planning and real-time decisionmaking in complex nearshore settings.

- Models are powerful tools to support decision makers in pre-planning, emergency response, and natural resource damage assessment
- Current dispersed oil models use simple approaches for approximating 3D hydrodynamic data, are incomplete, and lack validation
- Recommendations for improving models include:

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Report Recommendations
D.5 WILL USE REDUCE OVERALL IMPACTS?

- Improve ability to model physical components of dispersed oil behavior (variations in horizontal/vertical diffusivities, energy dissipation rates)
- Improve ability to predict concentrations of dissolved and dispersed oil, as specific components, to support toxicity analysis
- Validate how advective transport of entrained oil droplets is modeled
- Predict the formation of water-in-oil emulsions under a variety of conditions
- Conduct a sensitivity analysis based on 3D, oil-component, transport, and fate models; develop databases to support the oil-component assessment approach

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Report Recommendations
D.5 WILL USE REDUCE OVERALL IMPACTS?

Develop and fund a focused series of experiments to quantify the weathering rates and final fate of chemically dispersed oil droplets compared to undispersed oil.

- Ultimate fate of dispersed oil is poorly understood
- Greatest concerns in areas of high suspended solids/low flushing rates
- Insufficient information on oil:sediment interactions and biodegradation
- Data suggests chemically dispersed oil has lower tendency to form SPM agglomerates vs physically dispersed oil
- Concern about consumption of dispersed oil by plankton, then deposition as fecal matter or passage through food chain

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Report Recommendations
D.5 WILL USE REDUCE OVERALL IMPACTS?

The biodegradation kinetics and ultimate biotransformation products of dispersed oil, esp. high molecular weight PAH, should be investigated using indigenous microbial communities from seawater.

- Past research has yielded mixed results, thus cannot be used to predict the biodegradation rate of chemically dispersed oil
- Little data on biodegradation rates and products of compounds that are persistent and have chronic effects
- The fate of these persistent compounds is needed to predict the long-term ecological effects of dispersed oil

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Report Recommendations
D.5 WILL USE REDUCE OVERALL IMPACTS?

Develop and implement a series of focused toxicity studies to:

1) **predict photo-enhanced toxicity;**

   - For light sensitive organisms, studies have shown increased oil toxicity by factors of 2-100
   - Could significantly increase the "footprint" of impact area

2) **estimate the relative contribution of dissolved and particulate oil phases to toxicity; and**

3) **expand toxicity tests to include an evaluation of delayed effects.**

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Photo-enhanced Toxicity Issues

- Found lab studies significantly underestimate toxicity - due to sub-optimal light
- Accumulated PAHs via photosensitization increase toxicity of some PAHs (due to formation of highly damaging radical species)
- Potential for long-term and delayed effects

BUT:
- PAHs need to be accumulated
- Organisms need to be translucent (significant light penetration)
- Need to have significant light levels

SO WHO'S POTENTIALLY AT RISK?

- Translucent early-life stage larvae in water-column (surface layers)
- Benthic coral species

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Dissolved vs. Droplet Phase

- Routes of exposure include dissolved and oil-droplet, particulate phases
- Toxicity estimates often based on THC / TPH / PAH of test media
- No information on relative contribution of different phases

SO?

- Oil droplets can cause physical effects (smothering, physical coating and exposed tissue death, e.g. corals)
- Oil droplets may be an important route of exposure:
  - -oil droplet/gill interactions may facilitate uptake of dissolved aromatics
  - -ingestion of oil droplets for suspension-feeders
- Toxicity estimates based on total TPH may under- or over-estimate thresholds

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Report Recommendations

D.5 WILL USE REDUCE OVERALL IMPACTS?

Every effort should be taken to ensure that the spill response research community continues to monitor developments in the broad field of ecotoxicology, as various applications of increased understanding of toxicological effects, on various time scales, at the population and community-level may be of significant value to dispersant decisionmaking.

- Central issue in ecotoxicology
- Toxicological literature on individual organisms - readily studied
- How does loss of individuals affect a population?
- How does damage to populations affect communities?
- Population and community models show promise

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Report Recommendations
D.5 WILL USE REDUCE OVERALL IMPACTS?

Studies should be undertaken to assess the ability of fur and feathers to maintain the water-repellency critical for thermal insulation under dispersed oil exposure conditions comparable to those expected in the field.

- Was a recommendation of NRC (1989)
- Has not been adequately addressed
- Important assumption in the environmental trade-off analysis

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Report Recommendations
D.5 WILL USE REDUCE OVERALL IMPACTS?

Develop and implement detailed plans (including preposition of sufficient equipment and human resources) for rapid deployment of a well-designed monitoring effort for dispersant applications in the US.

- Develop an environmental monitoring guidance manual with sampling and analytical techniques, and QA/QC
- Develop a definition of field effectiveness
- Measure dispersed oil droplet size distribution and dissolved-phase TPH and PAH concentrations in filtered and unfiltered water

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HOW DO WE MAKE ALL THIS HAPPEN?

NOAA, EPA, DOI, USCG, relevant state agencies, industry, and appropriate international partners should work together to establish an integrated research plan, which focuses on collecting and disseminating peer-reviewed information about key aspects of dispersant use in a scientifically robust, but environmentally meaningful context.

However, it should be recognized that no amount of research or monitoring will eliminate uncertainty entirely.

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