Research Needs: Effectiveness of Dispersant Application and Fate of Dispersed Oil

University of New Hampshire

NOAA

Source of Research Needs

- CRRC Research Needs Workshop on Dispersed Oil
  - September 2005
  - Report in course packet

1. Chemical Parameters that Influence Overall Effectiveness

A. Literature synthesis on physical and chemical properties of oils that determine overall effectiveness of dispersant application

- Use existing data to develop tools to predict dispersibility
  - Function of composition and weathering
- Identify data gaps and recommend future studies to support development of inputs to models that better predict window of opportunity when dispersants will be effective
  - Bench-scale and wave tank tests

GOAL: Identify graphical products and empirical tools useful to decision makers

1. Chemical Parameters that Influence Overall Effectiveness (cont.)

B. Refine existing datasets to correlate physical and chemical properties of different types of oil with dispersibility

- Identify properties that determine dispersibility of a given oil
- Develop “groupings” of oil properties that help define dispersibility of unstudied oils
- Build on existing syntheses
- Need good statistical expertise to do this because complex, multivariate interactions must be quantified

GOAL: Provide necessary input data for models

- **Facilitate decision making by providing more realistic predictions of oil’s dispersibility**

University *of* New Hampshire

NOAA

1. Chemical Parameters that Influence Overall Effectiveness (cont.)

C. Protocols for creating weathered oil/emulsions

- Develop methods to create consistent and representative test oils for effectiveness testing
  - understand how weathering affects dispersibility
- Compare simple to more complex methods
  - Do simple methods produce weathered oils/emulsions that are representative of natural conditions?
- Test oils should have:
  - Different emulsification properties
  - Represent possible at sea slicks (rheological and chemical properties)
  - Collect and characterize samples from spill of opportunity and field tests

GOAL: Important component of other protocols and test systems to produce realistic results

University of New Hampshire

1. Chemical Parameters that Influence Overall Effectiveness (cont.)

D. Development of standard oils with known dispersibility over a range of variables for comparison with other oils

- Provide data for decision makers to better predict dispersibility of less-studied oil by comparison of its properties with well-studied standard oils
- Standard oils need to be in broad categories
  - Must be field or tank tested
- Oils selected on regional priorities

GOAL: Improve current ability to predict the effectiveness of dispersant application specific oil

1. Chemical Parameters that Influence Overall Effectiveness (cont.)

E. Develop and compare of methods for measuring droplet size distributions and energy dissipation rate in different dispersant effectiveness test systems

- Develop protocols and sensor systems for measuring droplet-size distributions
  - Bench-scale tests, wave tank tests, and field applications
- Evaluate methods and develop standard protocols to measure energy dissipation rates
- Synthesis of literature on horizontal and vertical energy dissipation rates for upper sea-surface turbulence under a variety of sea conditions T
  - Testing system conditions must correlate with typical sea values

GOAL: Improve value of test results by correlating to actual field conditions

1. Chemical Parameters that Influence Overall Effectiveness (cont.)

F. Implement a research program to fill identified data gaps in chemical dispersant effectiveness testing

- Generate data needed to better understand and predict dispersant effectiveness in field
  - Include energy dissipation rates, droplet size distributions, different dispersant types and dosages
  - Based on results of literature synthesis and standard protocols
- Should be a coordinated program of:
  - Bench scale testing followed by focused wave tank testing
  - More realistic mechanisms of energy input and weathered oil

GOAL: Improve ability to predict window of opportunity for effective dispersant application

2. Operational and Hydrodynamic Parameters that Influence Overall Effectiveness

A. Determine factors that represent realistic operational conditions for wave tank test systems

- Define and achieve operational effectiveness
- Establish realistic wave tank test conditions
  - Be able to correlate energy characteristics of wave tanks with realistic sea conditions
- Review on-going work-plans at existing wave tanks
  - Impact velocity, dispersant: oil ratio, oil thickness, wave dynamics, effects of currents on dispersant effectiveness
- Slick control for reproducibility
- Improve mass balance calculations

GOAL: Correlate bench scale and wave tank results to field energies

- **Provide improved information on which to choose platform and dosage and better predict effectiveness**

University of New Hampshire

NOAA

2. Operational and Hydrodynamic Parameters that Influence Overall Effectiveness (cont.)

B. Improve models of dispersed oil transport in upper mixed layer

- Literature search for data and methods that:
  - Measure key hydrodynamic properties of upper mixed layer C
  - Correlate wave and current dynamics to energy dissipation rate
  - Define layer below turbulent mixing, but above pycnocline/thermocline
  - Focus on the issues of dispersed oil transport
- Do data exist at scale useful for dispersed oil modeling in useful environment (e.g., estuaries, open water)?

GOAL: Improve physical transport components of models

2. Operational and Hydrodynamic Parameters that Influence Overall Effectiveness (cont.)

C. Update SMART monitoring protocols

- Identify data gaps and weaknesses
- Incorporate new technologies
- Create accessible databases/websites
- Upgrade existing methods
  - Do not re-invent program
  - Coordinate among agencies

Goal: Enhance assessment of dispersant efficacy with real-world data

University of New Hampshire

2. Operational and Hydrodynamic Parameters that Influence Overall Effectiveness (cont.)

D. Assessment of effects of dispersant application on subsequent mechanical recovery of undispersed oil

- Determine ability of mechanical methods to recover oil that has been treated with chemical dispersants, but not effectively dispersed
- Provide information on choice of mechanical equipment after dispersant use to recover remaining floating oil
- Address effects of dispersant dosage, oil type, equipment type, and temporal changes in oil

GOAL: Inform decisions about consequences of attempting dispersant application on marginally dispersible oil or at low mixing energy

2. Operational and Hydrodynamic Parameters that Influence Overall Effectiveness (cont.)

E. Optimize operational effectiveness of dispersant applications

- Understand how operating characteristics affect dispersant application and effectiveness
- Consider: evaporative processes, chemical composition at slick surface, effective droplet size range, spray systems, swath definition, wind effects, sea state, wind restrictions
- Best evaluated during field applications
  - Tests expensive and only representative of one condition
  - Value of spills of opportunity?

GOAL: Improve operational decisions regarding application parameters

2. Operational and Hydrodynamic Parameters that Influence Overall Effectiveness (cont.)

F. Evaluate new technologies for monitoring dispersant effectiveness in field

- Cost effective sensor systems to measure take water column measurements at various depths
- Quantitative measurement of:
  - Amount of oil dispersed; dissolved and particulate oil concentrations in the water column; oil over space and time; droplet-size distributions; oil/SPM interactions

GOAL: Provide operational data to support continued dispersant application and concentration data for model validation and effects assessment

University of New Hampshire

3. Modeling Integration of Chemical, Operational and Hydrodynamic Parameters

A. Workshop on requirements for integrating oil toxicity and biological data with oil fate and transport models

- Cross-training of modelers and scientists in physical, toxicological, and population models
- Identify additional research needed to improve models
- Questions:
  - How good do the answers have to be (validation standards)?
  - Where should fate models be improved?
  - What are important scales for assessing impacts (spatial and temporal)?
  - What bioassay data should be incorporated into models?
- Identify and quantify uncertainties

GOAL: Develop good, integrated models to support decision making

University of New Hampshire

NOAA

3. Modeling Integration of Chemical, Operational and Hydrodynamic Parameters (cont.)

B. Improve models to predict dispersant effectiveness and oil fate

- Incorporate results of earlier effectiveness projects into integrated models to predict effectiveness of dispersant applications
- Develop improved surface turbulence algorithms, relationship between energy dissipation rate and droplet size distributions, and operational application parameters
- Model output should include time series maps of droplet-size distributions; total dissolved and particulate hydrocarbons/PAH
  - Use data from tank tests, dispersant application tests, lab studies for different oils and environmental effects
- Should be open code

GOAL: Improved models for tradeoff analyses during preplanning and real-time response decisions

4. Fate of Oil and Dispersed Oil in the Water Column and Other Habitats

A. Understand interactions of chemically dispersed oil droplets with suspended particulate matter (SPM) and how affect oil biodegradation and fate of dispersed oil

- Develop a coalescence model and model inputs to predict the processes and interactions of chemically dispersed oil and SPM under field conditions
- Predict size and composition of oil/SPM aggregates and their buoyancy
- Understand interaction of multiple variables: SPM type (mineral, organic, biological), SPM size and density, oil type, oil droplet size, surfactant type, salinity, energy, aggregate characteristics

GOALS: Address concerns that dispersed oil will interact with SPM and deposit on bottom

Provide information on biodegradation rates of sedimented oil in high SPM zones (e.g., estuaries and surf zone)

4. Fate of Oil and Dispersed Oil in the Water Column and Other Habitats (cont.)

B. Degree, rate, and consequences of surfactant leaching from surface slicks and chemically dispersed oil droplets

- Data on rates of surfactant leaching from dispersed oil droplets and effect on oil droplet/SPM interactions, coalescence of individual oil droplets (i.e.,re-surfacing rate), and biodegradation rates
- Can surfactant leaching from treated floating slicks help determine effectiveness of initial oil dispersion
- Studies at realistic oil-to-water ratios and under different energy regimes
- Consider oil type, oil droplet size, surfactant type, surfactant application method
- Results reported as rates appropriate to scalable model

GOAL: Determine how long dispersant application under calm conditions is effective

Provide better data on fate of dispersed oil, particularly in areas of high suspended sediments

4. Fate of Oil and Dispersed Oil in the Water Column and Other Habitats (cont.)

C. Reconcile differences between empirical evaporation approach and traditional pseudo-component approach

- Improve algorithms to predict evaporation rates of surface slicks and chemical composition of dispersed oil
- Resolve whether to consider slick thickness in evaporation algorithms

GOAL: Better predict loading and fate of oil components in dispersed oil (particularly low molecular weight components that have greatest acute toxicity) as it mixes into water column and interacts with SPM

4. Fate of Oil and Dispersed Oil in the Water Column and Other Habitats (cont.)

D. Quantify biodegradation kinetics of dispersed oil

- Review results of past studies to identify weaknesses in previous test protocols
- Predict biodegradation kinetics of hydrocarbons and persistent PAHs in dispersed oil
  - Use oil-to-water ratios that follow significant dilution of the dispersed oil plume
- Develop inputs into dispersed oil fate model
- Address broad spectrum of constituents (emphasis on more persistent, high molecular weight PAHs)

GOAL: Determine rate of dispersed oil degradation in water column

4. Fate of Oil and Dispersed Oil in the Water Column and Other Habitats (cont.)

E. Improve, verify, and validate oil spill trajectory and fate models

- Improve ability to model trajectory and fate of dispersed oil
- Use spills of opportunity to verify models
- Determine hoe to address fact that better models are proprietary

GOAL: Improve and validate models to reduce concern of stakeholders that current models are inadequate

University of New Hampshire

5. Realistic Exposure Regimes/Toxicity Testing

A. Develop methods to collect and analyze dissolved phase and particulate/oil-droplet phase PAHs

- Do as function of time and space at spills of opportunity or field tests
  - Through comparison to PAH thresholds measured in toxicity tests and predicted in models
- Develop environmental monitoring guidance manual with sampling and analytical methods and quality assurance protocols and data quality objectives
- Provide detailed plan (e.g., pre-positioning of sufficient equipment and human resources), for rapid deployment at spills

GOAL: Develop appropriate toxicity testing methods and validate oil fate and effects modeling

University of New Hampshire

5. Realistic Exposure Regimes/Toxicity Testing (cont.)

B. Monitoring dispersed oil concentrations at spills of opportunity

- Improve operational monitoring at spills to document spatial and temporal concentrations of dispersed oil
  - Dissolved and particulate/oil droplet phase PAHs
  - Function of time and space
  - Review emerging technologies
- Compare to PAH thresholds measured in toxicity tests and predicted in models
- Note: Waiting for a spill of opportunity is high risk
- Tier 3 SMART addresses requirements for monitoring, but lacks detailed protocols and a team for implementation at spill emergencies

GOAL: Obtain field data for validation of all model components

5. Realistic Exposure Regimes/Toxicity Testing (cont.)

C. Literature synthesis of dispersed oil toxicity studies

- Provide data summaries of dispersed oil toxicity studies to:
  - Use in current risk assessments
  - Identify data gaps
  - Recommend future studies
- Should be in formats appropriate to:
  - Current risk assessment approaches (e.g., ERA workshops)
  - Integrated models
- Note inconsistencies in:
  - Dilution methods, exposure regimes, oil measurement methods and analytes (dissolved vs. particulate, nominal vs. measured, TPH vs. PAH), and endpoints

GOAL: Data will improve the quality of risk assessments and inform direction of future research

University of New Hampshire

5. Realistic Exposure Regimes/Toxicity Testing (cont.)

D. Standard methods for toxicity testing of dispersed oil appropriate for coastal regimes

- Develop methods such as near-shore CROSERF)
- Convene working group to review existing methods and develop new ones for toxicity testing that:
  - Have realistic concentrations and durations (exposures) of dissolved and particulate PAH and can measure of actual concentrations of both
  - Can measure ecological endpoints (lethal and sublethel acute effects and chronic effects), photo-toxicity, and appropriate species and life stages
  - Better estimate relative contribution of dissolved and particulate oil/PAH

GOAL: Obtain data that can assess impacts to water column resources during trade-off analysis in near-shore settings

6. Integration to Make Short and Long Term Prediction of Effects

A. Synthesis of existing dispersed oil toxicity data to support risk-based decision making for use of dispersants at spills

- Similar to previous research need
- Focus on oil, dispersants, and dispersed oil data for chronic and acute toxicity
- Format similar to NOAA's SQUIRT or Table 2-3 NRC (2005)
- Data with strong statistical basis and peer-reviewed
- Define role of chronic effects

GOAL: Improve trade-off evaluation by providing clear, peer-reviewed summaries of toxicity data

6. Integration to Make Short and Long Term Prediction of Effects (cont.)

B. Effects of dispersed oil on wildlife

- Determine thresholds of dispersed oil in water column that affect birds and fur-bearing mammals
- Compare dispersed and non-dispersed oil
- Endpoints should include effects of dispersant and dispersed oil on water-proofing of fur and feathers and thermoregulation
- Perform studies at realistic exposure conditions
  - Consider effects of leaching of surfactant

GOAL: Evaluate environmental tradeoffs that assume dispersant use reduces impacts of oil on wildlife

6. Integration to Make Short and Long Term Prediction of Effects (cont.)

C. Effects of short term exposure to dispersed oil

- Conduct short term toxicity tests identified in literature review or use new standard methods
- Consider:
  - phototoxicity
  - dissolved and particulate PAH fractions
  - standardized chemistry and endpoints (lethal, sublethal, and long-term)
- Develop protocols for estimating relative contribution of dissolved vs. particulate oil phases to toxicity

GOAL: Produce short term exposure results for evaluating impacts of dispersed oil

6. Integration to Make Short and Long Term Prediction of Effects (cont.)

E. Long term effects of short term exposures to dispersed oil

- Conduct long term toxicity tests (identified in literature review or use new standard methods)
- Use realistic exposure scenarios
- Include delayed effects: length/weight, abnormalities, enzymatic effects, reproduction, genetic abnormalities, and behavioral impacts (e.g., mating, flight, feeding)
- Develop protocols for estimating relative contribution of dissolved vs. particulate oil phases to toxicity

GOAL: Produce data on the long term effects for evaluating impacts of dispersed oil

University of New Hampshire

6. Integration to Make Short and Long Term Prediction of Effects (cont.)

F. Integration of fate and toxicity models with population models to predict short and long term effects of dispersant application

- Evaluate existing population models for applicability to episodic oil exposures and effects
- Extrapolate from existing population and existing data
- Extrapolating from toxicity tests to population- or community-level impacts is difficult

GOAL: Provide more quantitative analysis of consequences of dispersant use