The Use of Dispersants in Marine Oil Spill Response

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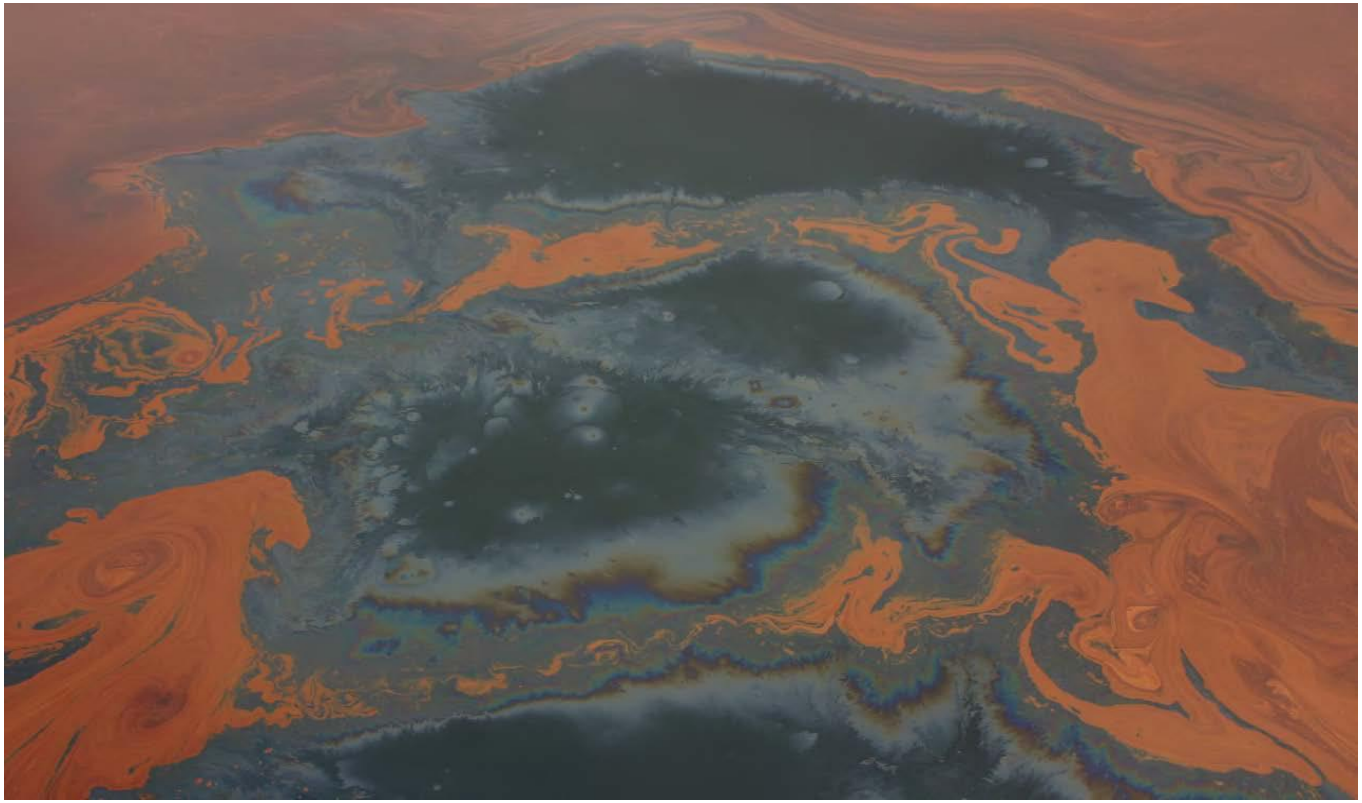
Ocean Studies Board
The National Academies of Sciences, Engineering, and Medicine

ITAC Meeting, Southampton, UK
October 2, 2019

Part 1: Susan Roberts



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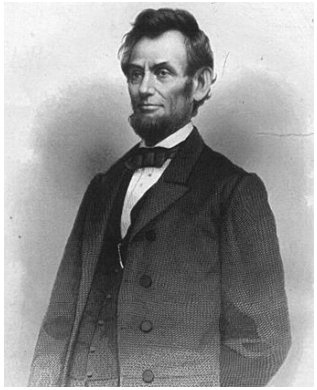
- "…The Academy shall, whenever called upon by any department of the Government, investigate, examine, experiment, and report upon any subject of science…"



1863 Congressional Charter of the
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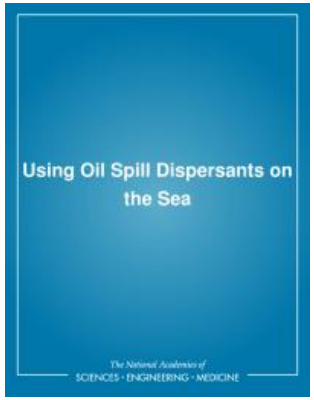
NASEM Study Process

- NASEM is a private, non-profit organization without dedicated funding. Activities are funded through contracts and grants, mainly from federal agencies.
- New projects originate with the boards, agencies, and Congress. The statement of task is negotiated with the sponsor(s), board members, and is subject to institutional oversight (NASEM governing board).
- Study committees are composed of experts chosen for expertise, balance, and objectivity (conflict of interest screening).
- Meetings convened for information gathering, deliberations, report writing, external peer review.
- Reports are briefed for sponsors, federal agencies, Congress, and news outlets. Reports are posted at NAP, free pdf download.

Previous Reports on Dispersants



1989: *Using Oil Spill Dispersants on the Sea*
(https://www.nap.edu/catalog/736/using-oil-spill-dispersants-on-the-sea)

2005: *Oil Spill Dispersants: Efficacy and Effects*

(https://www.nap.edu/catalog/11283/oil-spill-dispersants-efficacy-and-effects)

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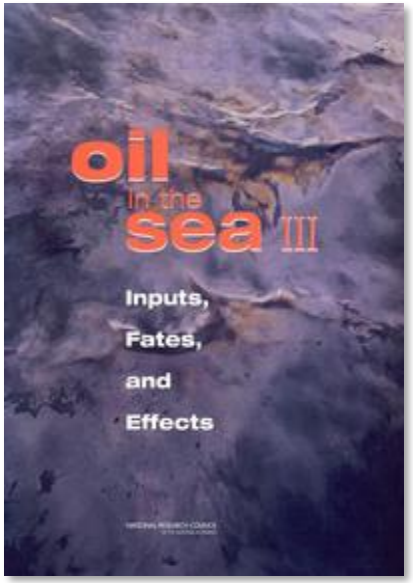
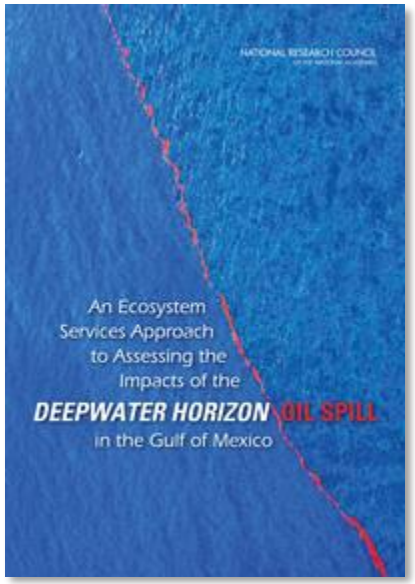
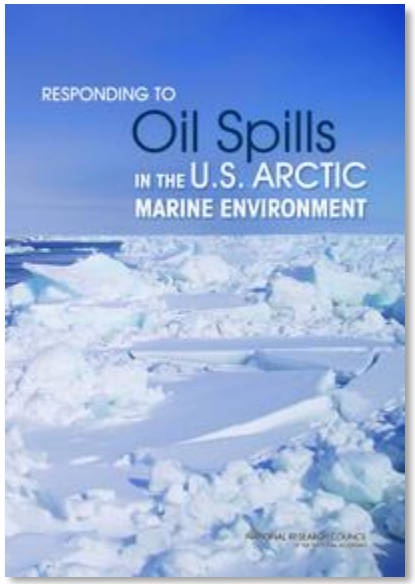
Other Oil Spill Reports







Abbreviated Statement of Task

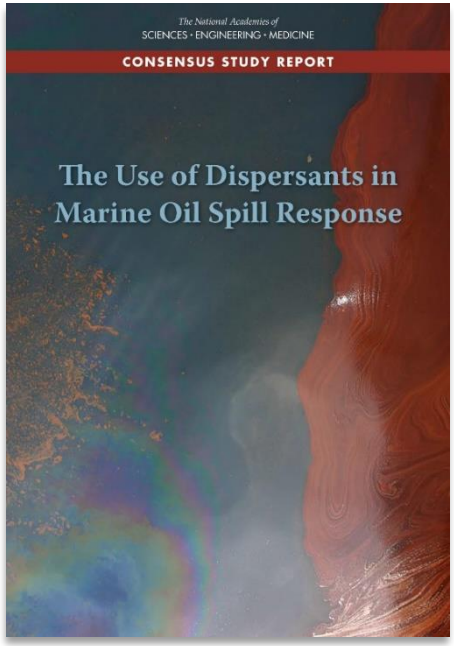
This study will assess the effects and efficacy of dispersants as an oil spill response tool through review and evaluation of research reports and results. The study will evaluate trade-offs associated with dispersant use, in part through use or review of net environmental benefit analyses conducted for past oil spills. This evaluation will include comparison of chemically dispersed oil with the fate and effects of untreated oil.

Tasks

- Assess the state of our knowledge about dispersant effectiveness and the fate of untreated oil, chemical dispersants, and chemically dispersed oil;
- Evaluate and summarize research on toxicity of chemical dispersant formulations, chemically dispersed oil, and untreated oil at realistic environmental exposure levels;
- Compare the benefits and limitations of dispersant application to the use of other clean-up methods;
- Compare the relative human health risks;
- Identify the research protocols and standards that would increase the applicability of lab-based measurements to the field and improve the comparability of research findings from different laboratories;
- Assess the adequacy of the existing information to support risk-based decision-making.

Report Roadmap

- **Chapter 1:** Introduction
- **Chapter 2:** Fate and Transport
- **Chapter 3:** Aquatic Toxicology and Biological Effects
- **Chapter 4:** Human Health Considerations
- **Chapter 5:** Tools for Decision-Making
- **Chapter 6:** Comparing Response Options
- **Chapter 7:** Research and Decision-Making Protocols



Committee Roster

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Introduction

- A variety of response options are required to address the diversity of circumstances, oil types, and environmental conditions under which oil spills occur.
- Dispersants promote formation of small droplets that become suspended in the water column; droplets promote dilution, dissolution, and degradation.
- Much of the literature since the 2005 report focuses on the DWH; however, ***this report is not a retrospective evaluation of that event.***

Dispersants
Fate and Transport

- Modern dispersants are a mixture of solvents and surfactants.
- Physicochemical properties determine their fate in the environment.
- Dispersant components are generally subject to rapid dilution, dissolution, and degradation.
- When injected at depth, components of dispersants differentially dilute and dissolve, with some more persistent components (e.g., DOSS) potentially being retained at depth.

Fate and Transport

- Fate and transport of oil depends on the location of the source, oil type and composition, and environmental conditions.
- Action of dispersants depends on type of oil, degree of weathering, and mixing energy.

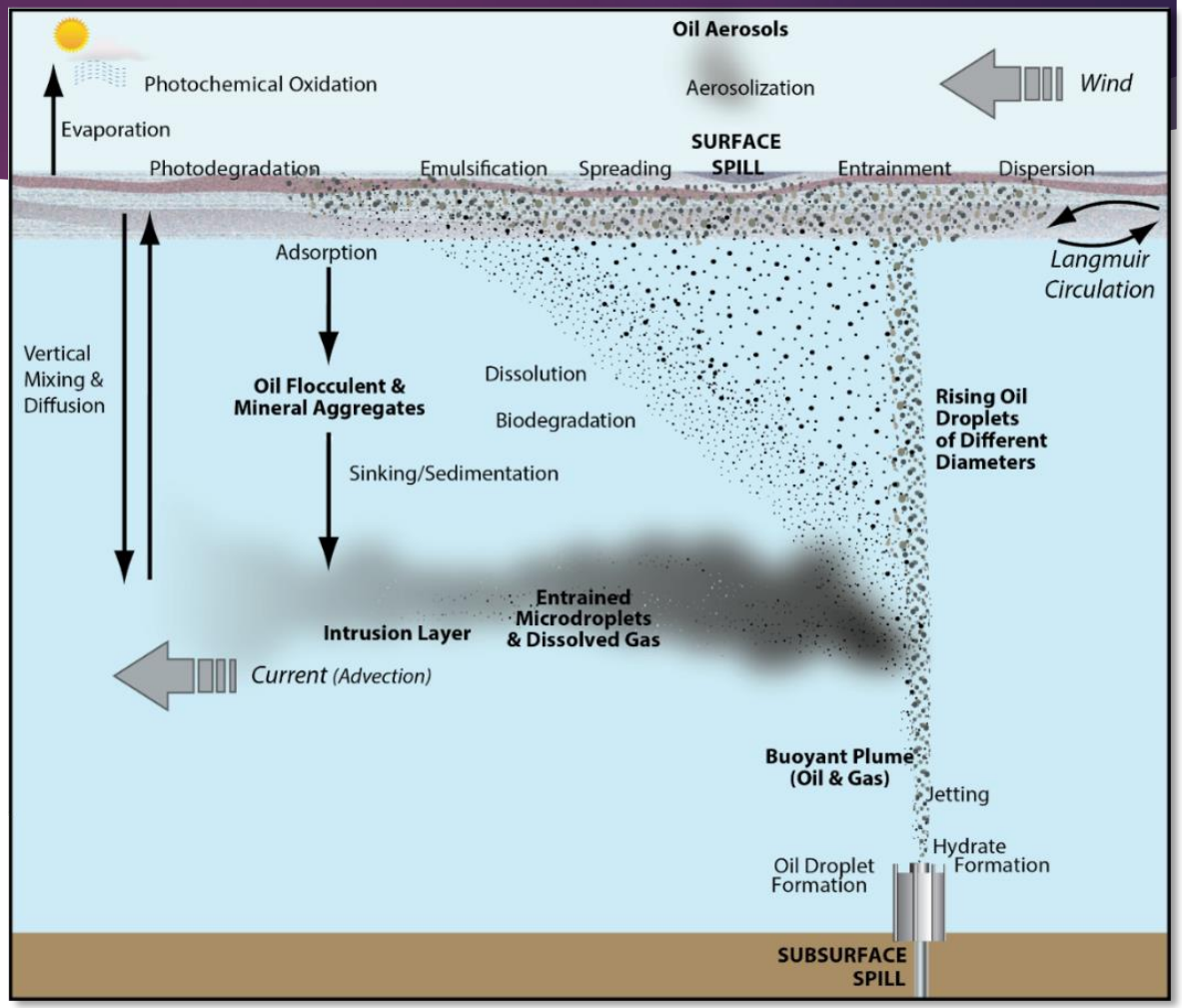


Figure S.1 & 2.1; Pages 5 and 28; SOURCE: Modified from Hazen et al. (2016).

Fate and Transport

- Oil droplet size is a major factor determining the fate and transport of spilled oil.
- Experimental systems and models provide insight on oil droplet formation and distribution; however, sources of uncertainty remain, such as tip-streaming, pressure gradients, and out-gassing.
- Additional observations of droplet formation are needed as close to field scale as possible.

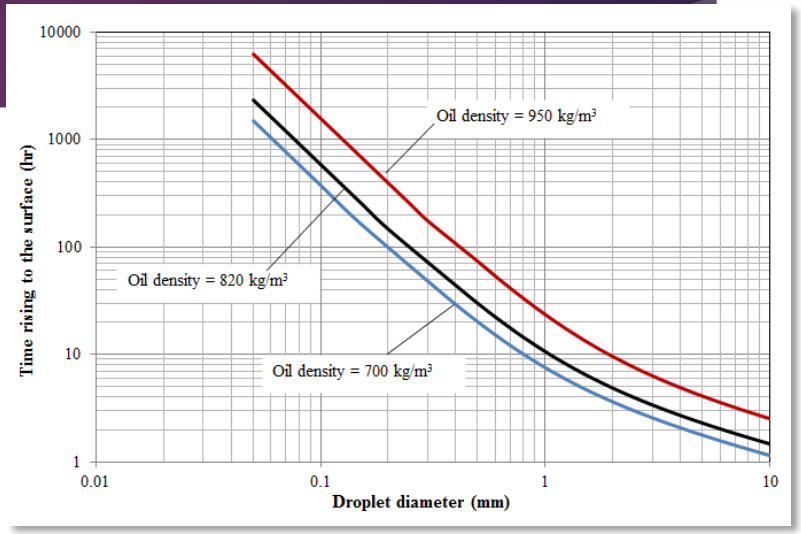
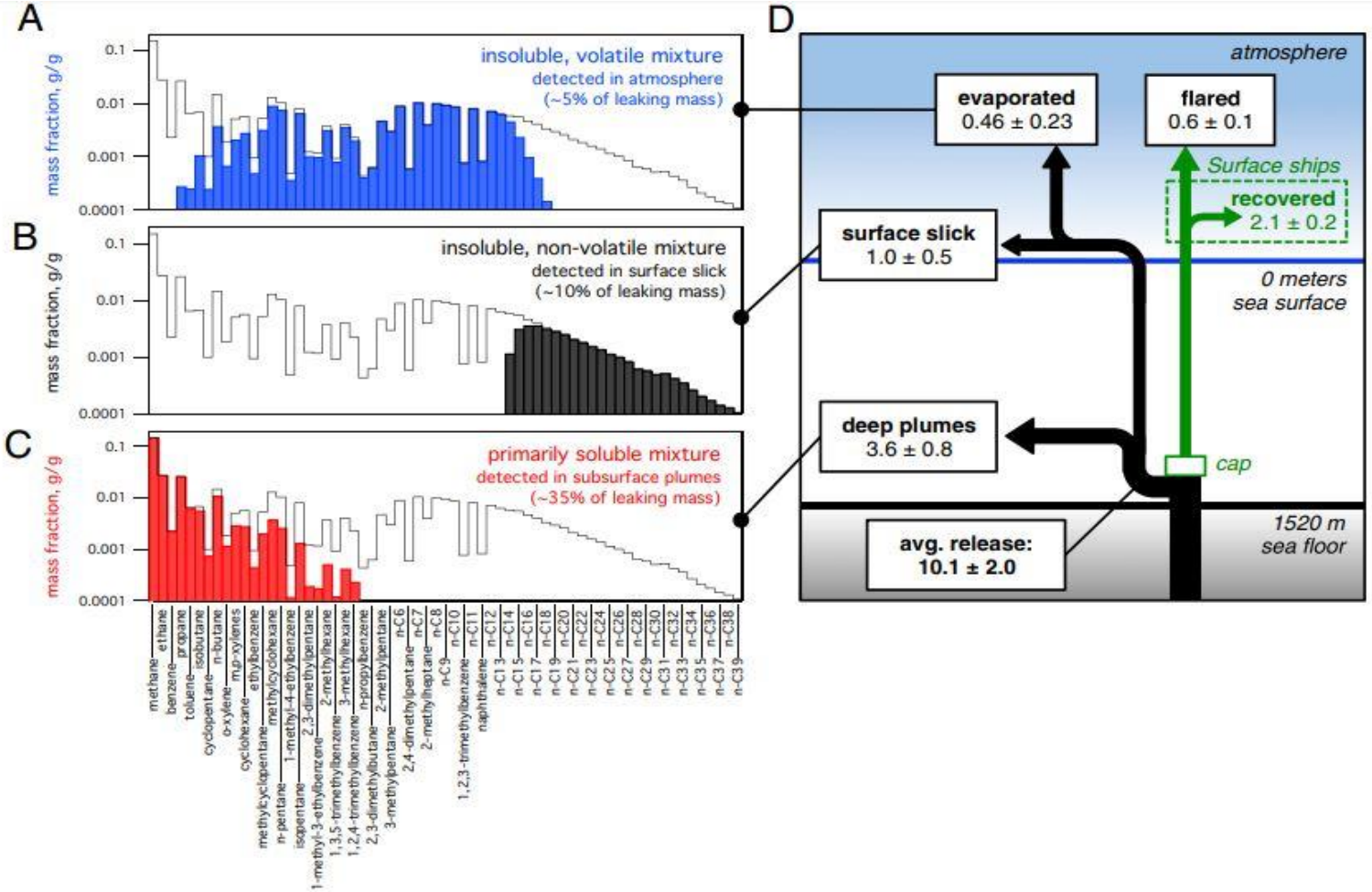


Figure 2.11; Page 55; Droplet rise in quiescent water for different oil densities; graph produced by the committee.

Recommendation: A model hindcast of the VOCs generated around the Macondo Well should be performed to better validate models and understand processes affecting VOC concentrations.

Fractionation of Oil

Figure 2.5, from Ryerson et al. 2012



Aquatic Toxicity of Dispersants

A review of existing laboratory-based dispersant-only toxicity data showed that when compared to field conditions, dispersant concentrations would be well below toxic thresholds

As underscored in the previous NRC reports, the primary concern is whether dispersed oil is more toxic than untreated oil, not the toxicity of modern dispersant formulations.

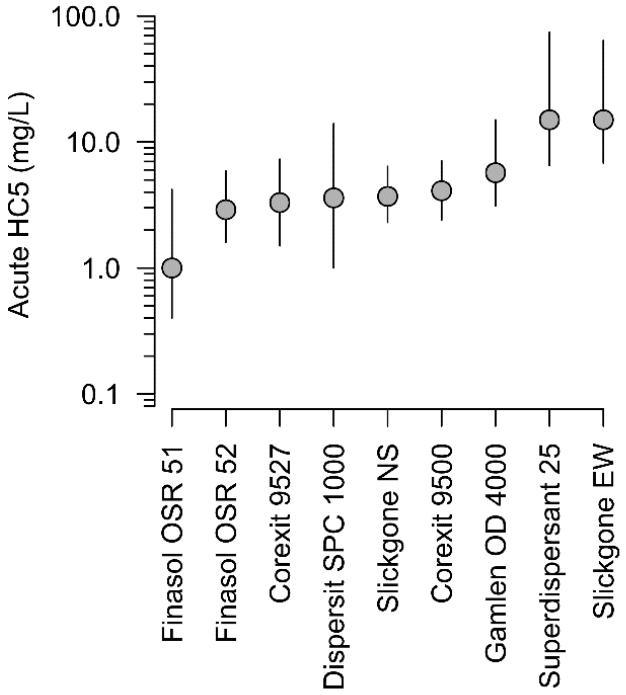


Figure 3.2; Data from Bejarano (2018)

Aquatic Toxicity

Variable loading used to compare WAF with CEWAF

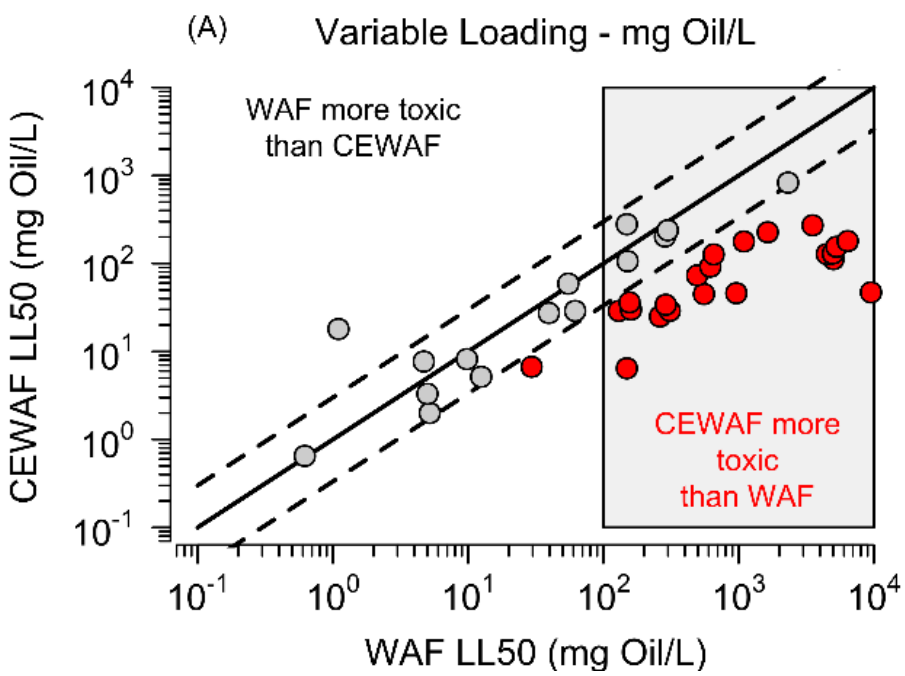


Figure 3.5a; Page 81; Data from Bejarano et al. (2014) and the Committee's meta-analysis (Appendix F).

Aquatic Toxicity and Biological Impacts

To determine the toxic effects of untreated and chemically dispersed oil on marine life, need to resolve four factors:

- Concentration exceeding known acute or chronic toxicity thresholds for the specific oil;
- Duration of exposure above toxic thresholds;
- Spatial and temporal distribution of marine life; and
- Species sensitivity to oil exposure above the acute or chronic toxicity thresholds.

Recommendation: The use of toxic units should be integrated into revised oil toxicity testing standards, evaluation criteria for models, and response option risk analysis. TUs make it possible to compare the toxicity of various mixtures of PAHs from different source oils and from mixtures that results from the differential solubility of oil constituents in seawater.

Aquatic Toxicity and Biological Impacts

Dispersants have been implicated in the formation of MOSSFA an aggregate that sediments and may affect benthic organisms.

Oiling and inhalation/aspiration of VOCs or oil droplets present hazards to surfacing animals (e.g., cetaceans, turtles, and birds) which may be reduced with effective chemical dispersion of surface slicks.

The hazard posed by dispersant use to wildlife under field conditions is not fully understood:

- Difficult to differentiate the impacts of chemically versus physically dispersed oil.
- Most research on oil impacts to wildlife has come from spills without dispersant use, or through controlled laboratory exposures.

Human Health

Primary oil constituents of concern: VOCs (benzene, toluene, ethylbenzene, and xylene [BTEX]) and PAHs.

Direct effect exposure pathways:

- Inhalational and dermal exposure to VOCs, dispersants or dispersed (aerosolized) oil for responders.
- PAHs and persistent dispersant components (DOSS) via seafood consumption.

Indirect effects

- Major oil spills are stressful to affected communities.
- Lack of transparency (e.g. dispersant formulation) enhances the stress levels and psychosocial situation.

Human Health

Epidemiological studies suggest consistent physical and psychological impacts of major oil spills; however studies examining direct effects of dispersants are limited. Two studies of DWH response workers reported effects associated with dispersant exposure; however these studies were protracted in initiation and relied on self-report of exposure.

- As part of planning efforts for future spills, biomarkers should be established for each dispersant formulation listed on the US EPA National Contingency Plan Product Schedule.
- In addition, reporting requirements should be improved to include details of injury and illness, with a focus on whether workers were exposed to dispersant.

Part 2: Tom Coolbaugh

Net Environmental Benefit Analysis (NEBA)

NEBA is a collection of tools to identify:

- Tradeoffs between response options
- Response option(s) most likely to minimize the net environmental impacts, given spill-specific conditions and potentially impacted resources.

NEBA is used for:,

- Strategic planning during the initial stages of a spill response,
- Tactical decisions during the active phase of a response,
- Contingency plan development

Decision-making Tools

Various tools developed to support the NEBA approach for oil spills:

- Consensus Ecological Risk Assessment (CERA)
- Spill Impact Mitigation Assessment (SIMA)
- Comparative Risk Assessment (CRA)
  - CRA relies on an integrated model adapted for a specific spill scenario
  - Time-consuming, hence it typically has more value for contingency planning

Recommendations: These tools should be expanded to address health (e.g., response personnel, community) and socioeconomic (e.g., beach closures) considerations. These tools should be used to gain stakeholder input on local/regional priorities, expand awareness, and gain trust in the decision-making process.

Comparing Response Options

Limited number of comparative studies have evaluated various response methods:

- TROPICS
- CRA SSDI Studies (CRA-1/CRA-2)
- Comparative VOC study
- Model of Gros et al. (2017)
- SIMA of Subsea Dispersant Injection

Report also highlights special considerations, such as:

- Regulatory approval process for dispersants
- Trans-boundary considerations
- Arctic considerations

Protocols

Methodologies, tools, and facilities for further research:

- Environmental Geochemistry Research
- Biodegradation Research and Modeling
- Meso-scale Test Facilities for Dispersant Studies
- Field Studies and Spills of Opportunity
- Droplet Model Validation
- Toxicity Testing
- Epidemiological Studies
- Risk Assessment Tools

Acknowledgments

Sponsors:

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- Gulf Research Program;
- Environmental Protection Agency;
- Bureau of Ocean Energy Management;
- American Petroleum Institute; and
- Clean Caribbean and Americas;

Reviewers of the report;

Meeting participants; and

Consultants Scott Socolofsky and Jonas Gros

Continuing the Discussion

Oil Spill Meetings:

- NRT/RRT briefing
- Clean Gulf 2019
- ICCOPR briefing
- ITAC
- GOMOSES 2020
- IOSC 2020

Public outreach:

- Possible workshops with Gulf Sea Grant programs
- Report in Brief

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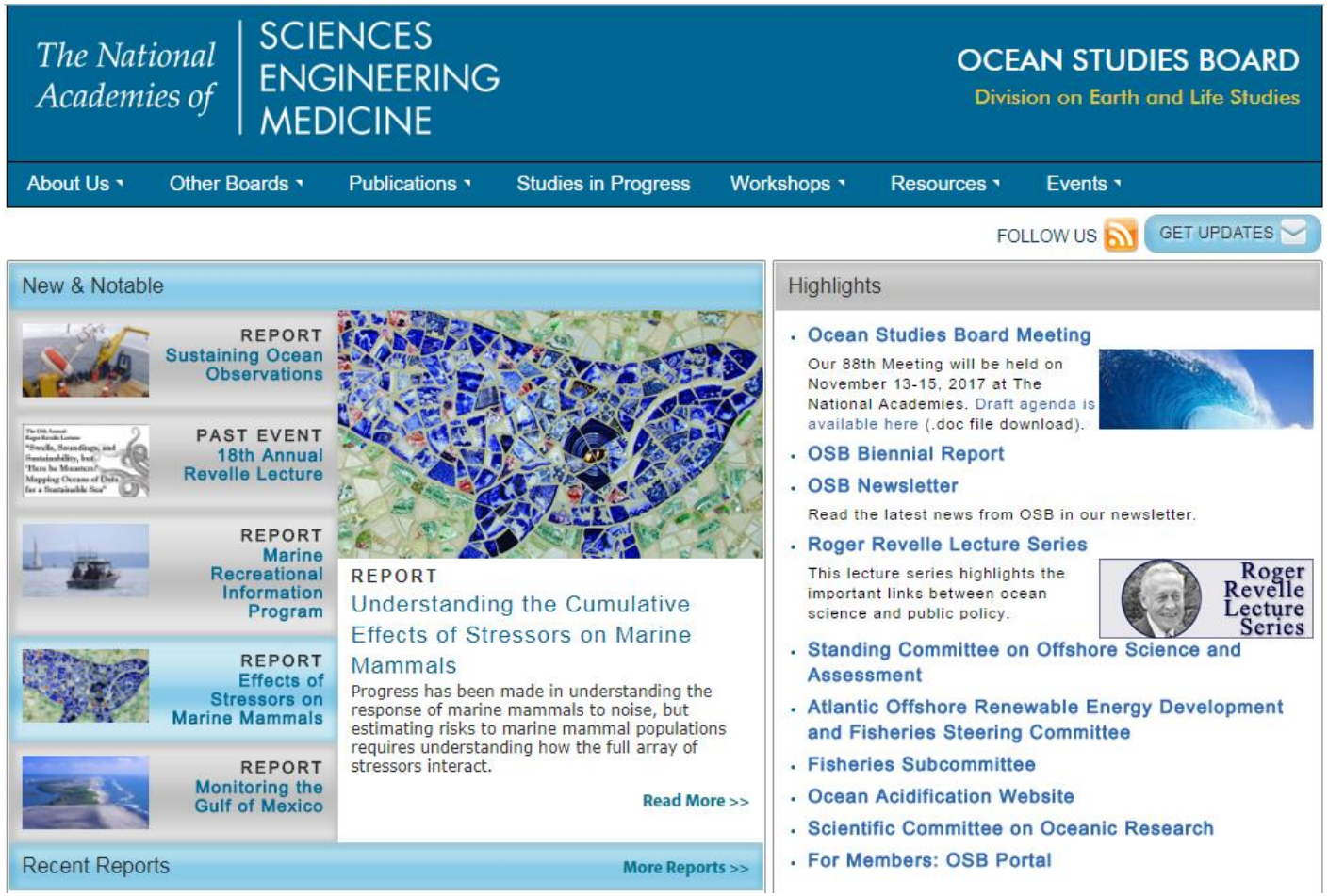
OSB Activities



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Free Reports

Aquatic Toxicity and Biological Impacts

Variable Loading

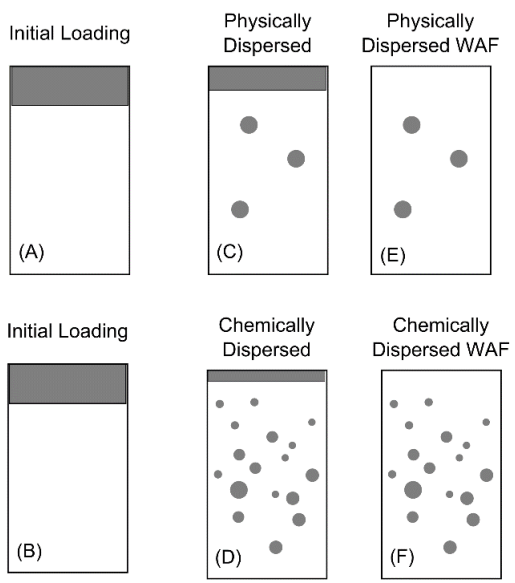

Figure 3.3; Page 80

Variable Dilution

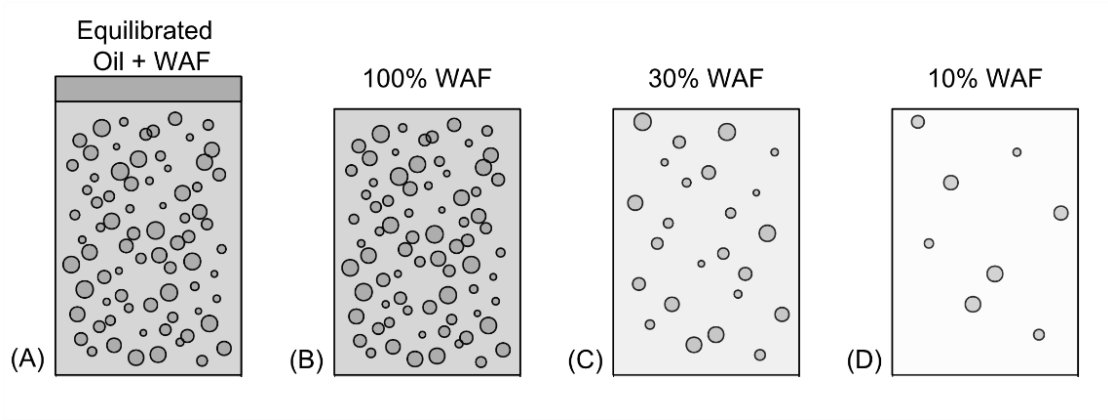

Figure 3.6; Page 83;

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Aquatic Toxicity and Biological Impacts

Field Data

Water + Oil = dissolved + oil droplets

Total PAH (Droplets + Dissolved)

$$TPAH = PAH_1 + PAH_2 + \ldots + PAH_N$$

Toxic Units (Dissolved)

$$TU_T = \frac{C_{W,1}}{LC50_1} + \frac{C_{W,2}}{LC50_2} + \ldots + \frac{C_{W,N}}{LC50_N}$$

PETROTOX

(1) Oil composition specified as a mixture of a number of blocks (10 -300)

(2) WAF **dissolved** concentrations estimated using Raoult's Law

(3) LC50s estimated using Target Lipid Model

(4) Total TU_T = sum individual TU_i = Dissolved $Conc_i$ / $LC50_i$