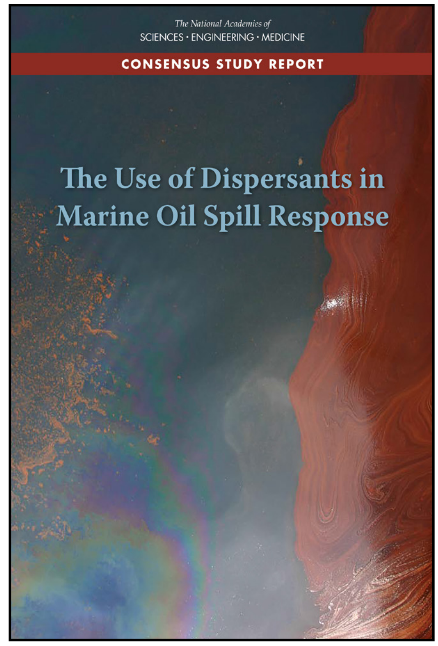
Consensus Study Report

HIGHLIGHTS

April 2019

The Use of Dispersants in Marine Oil Spill Response



The decision to use dispersants on any given oil spill requires careful comparison of its health and environmental impacts compared to other available response options, including leaving the spill untreated. Based on an evaluation of domestic and international research and results of field and laboratory studies, this report concludes that dispersant application in some circumstances can be a useful tool in oil spill response.

Oil is a mixture of thousands of compounds of widely varying physical and chemical properties, many of which are toxic and hazardous to human and aquatic health. Every oil spill, whether the result of an oil well blowout, vessel collision or grounding, leaking pipeline, or other incident at sea, presents unique circumstances and challenges. Many factors must be considered, including the type of oil, location, time of year, water depth, occurrence of living marine resources, environmental conditions, and potential community impact.

Responders need a variety of response options in their 'tool kit" to address any given oil spill. Typically, oil spill response tools are used to reduce the amount of floating oil at the surface, which may pose health risks for people (especially spill responders), as well as for seabirds and air-breathing marine species, such as sea turtles and marine mammals. Response methods include direct removal (via skimmers and booms), in situ burns, monitored natural attenuation, or application of dispersants. Dispersants lower the interfacial tension of oil and promote the formation of small droplets that become submerged in the water column. Natural attenuation and biodegradation processes can substantially contribute to reducing the volume of oil from a spill.

OIL SPILL RESPONSE DECISION-MAKING

Human life is the first priority in marine oil spill response. After immediate human safety, the next priority is development of a response strategy that most effectively reduces environmental consequences, offers the greatest protection, or promotes the fastest recovery.

Decision-making tools are used to estimate the likely fate and transport of oil and dispersant components and assess the effects associated with environmental exposure to oil and dispersant components. A number of approaches, collectively known as Net Environmental Benefit Analysis (NEBA), help decision-makers select the response option(s) most likely to minimize the net environmental impacts of oil spills. Three tools are commonly used to support the NEBA approach for oil spills are the Consensus Ecological Risk Assessment (CERA), Spill Impact Mitigation Assessment (SIMA), and Comparative Risk Assessment (CRA).

All tools used in the NEBA process rely to some extent on the ability to estimate a series of processes that influence where the oil goes and how oil composition changes over time (fate and transport), and the effects of oil on species throughout the affected ecosystem (aquatic toxicology and biological effects).

FATE AND TRANSPORT OF OIL AND DISPERSANTS

Modern dispersants (e.g., Dasic Slickgone NS, Finasol® OSR 52, Corexit® EC9500A) have been formulated for lower toxicity than the products used 50-60 years ago. They consist of a mixture of solvents and surface active agents (surfactants) with different environmental fates. Once released into the aquatic environment, dispersants are subject to rapid dilution, dissolution, biodegradation, and photodegradation processes. Consequently, there is just a brief time window after application in which ocean biota might encounter the full dispersant formulation.

Many types of oils, including crude oil and refined products, may be released into the marine environment during a spill, at which point their composition begins to change. The oil type, or chemical composition, determines the long-term behavior of oil. The oil's chemical composition also influences the action of dispersants; dispersants are more effective on lighter oils than on high viscosity oils.

Since the Deepwater Horizon (DWH) spill, models have been developed to better represent the processes determining droplet size and transport for both surface and subsurface spills. However, sources of uncertainty remain, including processes such as tip streaming, pressure gradients, and out-gassing. Additional modeling and field-scale experimentation is needed for more accurate predictions of oil fate and transport.

AQUATIC TOXICOLOGY AND BIOLOGICAL EFFECTS

Oil can present an immediate hazard to ocean life, both at the surface and below. Dispersants have been applied offshore to reduce hazards at the spill site and reduce the risk that the surface oil will be blown to nearshore habitats. However, dispersants increase the amount of oil that remains in the water column, both as dissolved oil constituents and as small droplets, where fish and other species may be exposed through absorption or ingestion.

Concerns over the substantial use of dispersants during the DWH spill triggered an expansion of research on the toxicity of oil, dispersed oil, and dispersants. Toxicity studies have been conducted by exposing biota to various oil and oil/dispersant mixtures under laboratory conditions. In most experiments, the conditions in the laboratory are not designed to be analogous to conditions in the field, but rather to identify threshold concentrations for a variety of marine species to evaluate potential effects of oil and dispersants on water column species.

However, the results of laboratory studies have been equivocal, at least in part due to a lack of consistency in the preparation of media, exposure procedures, and chemical analyses. This report suggests an approach for using results from many studies to develop a coherent analysis of the toxicity of dispersants and chemically dispersed oil.

Dispersant and Dispersed Oil Toxicity

Modern dispersants have been formulated with less-toxic chemical constituents, employing ingredients found in common consumer products such as cleaners and cosmetics. However, lack of full disclosure of substances comprising the dispersant formulations following use in the DWH spill contributed to public concern about toxicity. To assess the relative toxicity of dispersed oil, many laboratory studies have compared solutions of oil equilibrated with seawater to oil and dispersant mixtures equilibrated with seawater. Based on results from many experiments employing many different aquatic species, dispersants do not increase the toxicity of oil. At high oil loading, microdroplets formed in the presence of dispersants appear to add to the overall toxicity of the solution.

Phototoxicity

Another consideration for assessing the use of dispersants is phototoxicity. When oil is exposure to sunlight, the toxicity of certain polyaromatic hydrocarbons (PAHs) that are absorbed by the organism can undergo a 10-100 fold increase in toxicity. Use of dispersants to reduce oil at the surface would therefore lower the potential aquatic toxicity of the oil. Exposure to sunlight can produce new compounds that have to be considered.

Determining Effects of Dispersant Use

Toxicity models used together with environmental fate models can help evaluate the exposure and toxicity associated with various oil spill response options. Comparing the toxic effects of untreated and chemically-dispersed oil on marine life requires evaluation of 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

HUMAN HEALTH CONSIDERATIONS

The key questions with regard to human health are whether dispersant use alters the health risk associated with an oil spill through (1) direct effects of dispersant use, (2) effects of dispersant and oil mixtures, or (3) indirect effects of dispersant use changing the extent or duration of the spill.

During oil spill response, primary exposure pathways of concern are inhalational and dermal exposure of response workers. Direct effects on response workers can be mitigated through a proper worker health and safety program that focuses on personal protective equipment and monitoring. Community health concerns arising from exposure to oiled shorelines, and socioeconomic effects, such as disruption of commercial and subsistence fisheries, and concerns over contaminated seafood also need to be considered as a factor in oil spill response.

Human Exposure and Toxicity of Oil

The primary constituents of crude oil that can affect human health are the volatile organic compounds (VOCs) (benzene, toluene, ethylbenzene, and xylene [BTEX]) and PAHs. The carcinogenicity of benzene and PAHs, particularly benzo(a)pyrene, are well characterized. Dispersants may reduce exposure to these oil constituents by altering their fate, transport, and biodegradation.

In a deep-water blowout, subsea use of dispersants could reduce the potential for inhalational exposure by increasing the dissolution of VOCs during the slower transit of dispersed oil droplets to the surface. In addition to exposure to VOCs at the response site, VOCs released during an oil spill can contribute to the formation of secondary air pollutants, such as ozone, which could lead to inhalational exposure downwind from the spill location. Dermal exposure to oil constituents has been shown to cause skin irritation and skin cancer. At present, there is insufficient evidence to determine if dispersant use changes the transdermal absorption of crude oil components.

Although responders could be exposed to oil and/or dispersants through accidents or improper use of protective gear, broader community exposure to dispersants or dispersant/oil mixtures is much less likely because dispersant use is limited to offshore spills. Possible routes of exposure include ingestion, inhalation, and dermal contact. Exposure via ingestion could occur through consumption of seafood contaminated with PAHs or dispersant components during or after an oil spill. Protocols for closing and reopening fisheries during and after an oil spill are designed to protect public health from this exposure route.

If a response tool, such as dispersants, shortens the intensity and duration of a spill and hence response activities, and proper health and safety measures are in place, exposure risk would be lower, particularly for responders. This factor merits inclusion as part of the tradeoff considerations with regard to decisions on dispersant use.

Epidemiological Studies

Two studies of DWH spill responders have attempted to disentangle the direct effects of dispersants from other worker health risks. While these studies noted similar adverse effects associated with dispersant exposures, both have limitations in their ability to validate exposure to dispersants based on self-reporting of workers.

In both of these epidemiological studies, limitations in the exposure assessment for dispersants affect the strength of the conclusions. The protracted initiation of the studies and the lack of a dispersant/dispersed oil biomarker necessitated reliance on self-reporting, making it difficult to accurately estimate exposures and hence the effects of dispersant/dispersed oil versus untreated oil.

Indirect Human Health Effects

Often, the adverse health effects noted in studies of communities near an oil spill have been associated with psychosocial and economic impacts rather than toxicity associated with direct exposure to chemicals. A spill can also lead to prolonged closure of fisheries, causing secondary effects on community psychological and socioeconomic well-being.

SELECTION OF RESPONSE OPTIONS

It can be difficult to make trade-off decisions during an on-going spill based on field data, because observations may be limited. Efforts to ensure human safety, contain the oil, and minimize environmental damage take priority over monitoring and scientific studies. Pre-spill planning and scenario development prior to a spill provide the knowledge base on which decisions can be made during a spill event as long as human health considerations are included in the NEBA tools as discussed above.

Comparative Studies

A limited number of comparative studies have evaluated the effectiveness, benefits, and limitations of various response methods. For example, Tropical Investigations in Coastal Systems (TROPICS) established three shallow-water study sites from 1983 to 2015 in Panama to evaluate the impacts of untreated and dispersed oil relative to a control site. The purpose of the study was to evaluate the relative health of the ecosystem at each site. In the first 10 years, the plot exposed to dispersed oil had recovered to pre-spill conditions, while the site exposed to undispersed oil still showed negative effects on the mangroves (Renegar et al., 2017).

Another study involves a comparison of VOCs emitted to the atmosphere near the well during a DWH-like blowout using an integrated oil-fates model for the ocean and a numerical model for the atmosphere to compare use of subsurface dispersants with no response. The study concludes that subsurface dispersants reduces peak VOCs by factors of 100-200 fold depending on the winds.

Based on results from these and other field and modeling studies, surface and subsurface dispersant application represents a useful tool for oil spill response. When used appropriately, dispersants decrease the amount of oil at the surface, thereby reducing the potential exposure of response personnel to VOCs and decreasing the extent of oiled areas encountered by marine species at the surface.

Our understanding of the impacts of dispersants as a response tool has been greatly advanced by laboratory experiments and modeling but these efforts are often limited by their inability to capture the complexity or scale found in the field. Important issues that are best answered in a field study or spill of opportunity (SOO) include validation of models, especially scaling of droplet size, better understanding health impacts on response workers, validating response-decision making approaches, and discovering previously unknown linkages in complex ecosystems affected by oil.

Given its long-term funding and mandate, the NASEM Gulf Research Program, or a foundation with similar long-term funding, would be in an ideal position to work with the Interagency Coordinating Committee on Oil Pollution Research (ICCOPR) to coordinate a field experiment or scientific efforts for deployment in a SOO.

COMMITTEE ON EVALUATION OF THE USE OF CHEMICAL DISPERSANTS IN OIL SPILL RESPONSE

Mary E. Landry (*Chair*), United States Coast Guard (retired); **E. Eric Adams,** Massachusetts Institute of Technology; **Adriana Bejarano,** Research Planning, Inc.; **Michel C. Boufadel,** New Jersey Institute of Technology; **Gina Coelho,** (Retired) Sponson Group Inc.; **Thomas S. Coolbaugh,** Exxon Mobil Corporation; **Dominic M. Di Toro,** University of Delaware; **Julia Gohlke,** Virginia-Maryland College of Veterinary Medicine; **Terry Hazen,** University of Tennessee; **Kenneth Lee**, Fisheries and Oceans Canada; **Steven A. Murawski**, University of South Florida; **W. Scott Pegau**, Oil Spill Recovery Institute; **Ronald Tjeerdema**, University of California, Davis; **David L. Valentine**, University of California, Santa Barbara; **Helen White**, Haverford College; **Bernard D. Goldstein**, University of Pittsburgh Graduate School of Public Health. Staff from the National Academies of Sciences, Engineering, and Medicine: **Stacee Karras** (Study Director), **Susan Roberts** (Board Director), **Trent Cummings** (Senior Program Assistant).

For More Information . . . This Consensus Study Report Highlights was prepared by the National Academies of Sciences, Engineering, and Medicine based on the Consensus Study Report *The Use of Dispersants in Marine Oil Spill Response* (2019). The study sponsored by the Gulf of Mexico Research Initiative, National Academies' Gulf Research Program, Bureau of Ocean Energy Management, U.S. Environmental Protection Agency, American Petroleum Institute, and Clean Caribbean and Americas. Any opinions, findings, conclusions, or recommendations expressed in this publication do not necessarily reflect the views of any organization or agency that provided support for the project. Copies of the Consensus Study Report are available from the National Academies Press, (800) 624-6242; http://www.nap.edu or via the Ocean Studies Board web page at http://www.nationalacademies.org/osb.

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