ASSESSING DISPERSANT USE **TRADE-OFFS**

SpillPrevention.org

Things You Should Know

When oil is spilled some level of negative effects is likely.

Decision-makers use a Net Environmental Benefit Analysis (NEBA) process to identify the response action(s) that will result in the least long-term environmental impacts.

NEBA is a consensus-based tool that allows decision-makers to use input from stakeholders, subject matter experts, regulators, and responsible parties.

A NEBA assesses trade-offs of the various response options to determine which options will minimize both the short-term and long-term impacts of a spill.

NEBA trade-offs associated with dispersant use focus on impacts to sensitive shorelines and surface dwelling resources (wetlands, birds, marine mammals, turtles) versus resources that exist in the water (fish, corals, etc.).

Overview

Dispersants are products used in oil spill response to enhance natural microbial degradation, a naturally occurring process where microorganisms remove oil from the environment. All environments contain naturally occurring microbes that feed on and break down crude oil. Dispersants aid the microbial degradation by forming tiny oil droplets, typically less than the size of a period on this page (<100 microns), making them more available for microbial degradation. Wind, current, wave action, or other forms of turbulence help both this process and the rapid dilution of the dispersed oil. The increased surface area of these very small oil droplets in relation to their volume makes the oil much easier for the petroleum-degrading microorganisms to consume.

Dispersants can be used under a wide variety of conditions since they are generally not subject to the same operational and sea state limitations as the other two main response tools — mechanical recovery and burning in place (also known as in-situ burning). While mechanical recovery may be the best option for small, near-shore spills, which are by far the majority, it has only recovered a small fraction of large offshore spills in the past and requires calm sea state conditions that are not needed for dispersant application. When used appropriately, dispersants have low environmental and human health risk and contain ingredients that are used safely in a variety of consumer products, such as skin creams, cosmetics, and mouthwash (Fingas et al., 1991; 1995).

This fact sheet summarizes the trade-offs and evaluation factors used by decision-makers to determine whether the use of dispersants is warranted for an oil spill. It is intended to provide a clearer understanding of dispersants, how their use is authorized, and their consideration in the NEBA decision-making process.

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Introduction

When an oil spill occurs, decision-makers must be prepared to quickly determine the best response countermeasures for the incident-specific conditions. In most instances, government decision-makers conduct a rapid Net Environmental Benefit Analysis (NEBA) to compare and rank the pros and cons (or "trade-offs") of different response options relative to the spilled oil's potential impact on resources and the environment. In some cases NEBA is performed in advance of a potential spill during the planning stage and is then validated during a spill in an expedited manner. For each spill, the response options are evaluated to determine which option or set of options, given the incident-specific conditions, will result in the best outcome for the environment. They must determine if it is better to allow surface oil to remain, potentially impacting shorelines and wildlife that utilize the water surface, or use response options like dispersants, which would minimize the risk to surface resources but increase the potential risk to water-column organisms.

Net Environmental Benefit Analysis (NEBA)

The Net Environmental Benefit Analysis (NEBA) is a consensus-based planning tool that is used to bring natural resource trustees together to address resource-management decision-making needs for an oil spill response. NEBA provides a means to evaluate the likely environmental actions and make an assessment of the required trade-offs associated with them, considering possible impacts to sensitive resources and the environment. The NEBA analyzes the "trade-offs" of the response options, including natural recovery (no human intervention) to determine which option or combination of options can best reduce the spilled oil's overall impact, both the short-term and long-term, in the spill area.

Throughout the world, the advantage of implementing NEBA during the decision-use process has been demonstrated. The first example of a US-based NEBA oil spill evaluation occurred in 1990 when decision-makers assessed whether a mechanized "rock-washing" technique would provide benefit to the environment during the *EXXON VALDEZ* response (Tebeau, 1995). During the M/V *AMORGOS* grounding and subsequent break-up in January 2001 in Taiwan, dispersants were initially not permitted as the area of dispersant use was over unknown sea floor communities including possible coral reefs. After dive surveys revealed that there was less than 5% coral and the area was more of a "hardground community," the decision was made that there was a net environmental benefit to disperse the oil in order to prevent it from coming on-shore (Purnell, 2002).

In the United States, the formal NEBA process is conducted before a spill during the planning phase at the Area and Regional Response Team levels with input from state and federal participants to determine the benefits and limitations (or trade-offs) from using each response technology within their individual areas of responsibility. This evaluation is generally conducted in the contingency planning process. Following an incident, it may be reviewed again as additional knowledge and lessons learned are gained. For more information on the US-based dispersant approval process, refer to **Fact Sheet #5 – Dispersant Use Approvals in the United States**.

Trade-off Decision-making for Dispersants

Careful consideration is given before applying dispersants and many factors are analyzed prior to approval.

Toxicity of the oil, dispersed oil, and the dispersant itself are evaluated. Although dispersants are less toxic than the oil itself and do not increase the toxicity of oil/dispersant mixtures, their use during an incident is intended to transfer the oil from the surface into the water column. The trade-offs between surface and water-column effects must be carefully weighed.

Those in charge of a spill response must evaluate the likely effectiveness of dispersant use on the oil spilled. In most cases, dispersant use has a window of opportunity before processes such as weathering render it less effective. For this reason, it is important that responders not delay the decision making process for dispersant use (refer to **Fact Sheet #3 – Fate of Oil and Weathering** for more information on this topic).

If it is determined that dispersants will provide value to the response and the associated tradeoffs are acceptable, the individual in charge may authorize the use of dispersants. In the US, the Federal On-Scene Coordinator (FOSC) is the only official that can give this final authorization.

Exposure Routes

The primary pathways for exposure to spilled oil, dispersant, and dispersed oil may be defined as (see, for example: US National Oceanic and Atmospheric Administration or NOAA Fisheries, 2012 and US Fish and Wildlife Service or USFWS, 2010):

- **Inhalation** – For volatile organic compounds (VOCs), such as benzene, toluene, and others, inhalation is the primary route of exposure.
- **Ingestion** – This includes polycyclic aromatic hydrocarbons (PAHs) that are taken up by seafood and have the potential to ultimately be consumed people.
- **Dermal or surface contact/coating** – This is also considered a significant route of exposure for wildlife and the environment.

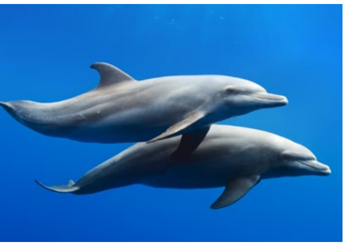
Resources of Concern

In general, there are four broad categories of resources/habitats that are most likely to be exposed to crude oil spilled on or in water: 1. Surface dwelling animals; 2. Water column resources; 3. Benthic/bottom dwelling resources; and 4. Intertidal and shoreline resources. In addition, socio-economic factors should be considered since amenities such as tourist beaches and marinas may contribute significantly to a region and may be affected by an oil spill or the resulting response (Baker, 1995). Examples of typical species and possible environmental effects of oil on these resources are discussed below.

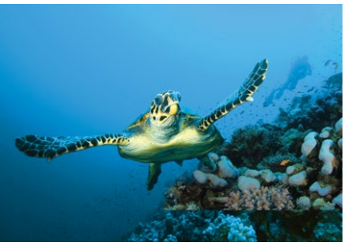
1. Surface Dwelling Animals

This group consists primarily of marine birds, marine mammals, and sea turtles.

Highly vulnerable bird species are those that are closely associated or fully dependent on the marine environment – diving for food, roosting on the water surface, etc. When birds come in contact with surface oil, the exposure can result in fouling of plumage, ingestion of oil, negative effects on reproduction, and death (USFWS, 2010).

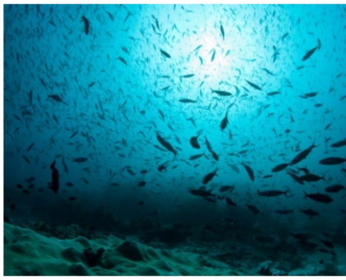


Most marine mammals, such as whales, dolphins, pinnipeds (e.g., seals), and sea otters, are dependent on the marine environment for their existence. As they must breathe air, the most likely routes of exposure to spilled oil for marine mammals include oiling of hair/skin, ingestion, and inhalation of toxic vapors when surfacing. Impacts from long term exposure to oil continue to be studied; however, recent studies indicate that marine mammals have an increased susceptibility to infection, loss of unborn young, and death (NOAA Fisheries, 2010). Behavioral alterations may also be observed such as stranding and obsessive grooming.



Sea turtles, like marine mammals, can be subjected to oiling from direct surface fouling, ingestion and inhalation of toxic vapors (NOAA Fisheries, 2010).

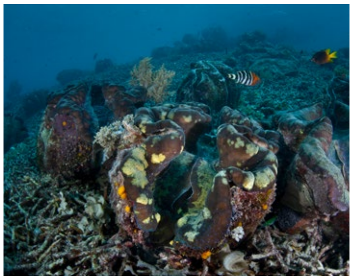
2. Water Column Resources



The routes of exposure for fish and plankton include direct exposure to dispersed oil. Some studies of adult fish have documented reduced growth, internal organ impacts, fin erosion and reproductive impairment when exposed to oil. Oil has the potential to impact spawning, since eggs and larvae are very sensitive to oil (USFWS, 2010).

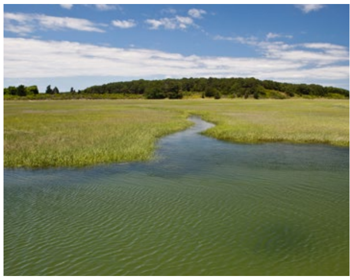
Most fish in the open ocean are able to leave an affected area and do not generally experience short term mortalities due to exposure to oil on the surface. Plankton and planktonic life stages of many marine species, however, appear to have a wide range of sensitivities when exposed to crude oil as they are not actively able to remove themselves from the contaminated environment and drift with the surrounding wind and currents. However, dispersed oil concentrations in the water column will rarely exceed toxic threshold levels and will decrease rapidly under real world conditions (George-Ares and Clark, 2000).

3. Benthic / Bottom Dwelling Resource



Benthic and bottom dwelling plants and animals such as seagrass, oysters, and other shellfish are typically only lightly affected from oil in the water column. Primary exposure is usually the result of direct contact/coating/smothering. In general, most marine plants are quite resilient (USFWS, 2010).

4. Intertidal and Shoreline Resources



The species and resources in intertidal and shoreline zones spend most of their time under water, but may be exposed to surface oil during low tide. They are often the most visible and severely impacted organisms.

The extent of impacts to these resources will be based on the sensitivity of the species being oiled and the duration and extent of oil exposure. Intertidal organisms can include crabs, clams, grasses, etc. Primary exposure pathways are typically from direct contact/coating/smothering. As most intertidal shellfish are filter feeders, they may ingest oil present in the water column (USFWS, 2010).

Exposure & Effects with Dispersants

When used appropriately, dispersants act to decrease the amount of oil on the water's surface, thereby reducing potential impacts to coastal areas by helping it mix into the water column as very small droplets. By keeping oil off of sensitive shorelines, the use of dispersants can significantly improve the rate of overall environmental recovery (Sell, et al., 1995). The formation of small droplets that remain dispersed in the water column promotes the oil's dilution and subsequent removal by microbial biodegradation. The following topics summarize possible changes in environmental exposure and effects due to dispersant application. While not discussed explicitly here, as mentioned above, socio-economic considerations are an important topic when considering the potential effects of an oil spill and subsequent response activities.

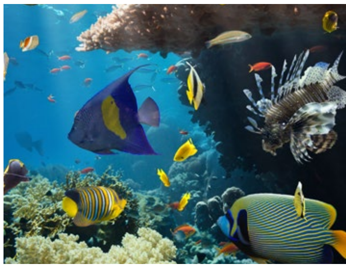
1. Surface Dwelling Animals

Removing the oil from the surface of the water with the use of dispersants will benefit surface-dwelling birds, mammals, and sea turtles by reducing the chance for exposure and oiling of skin, fur, and feathers or ingestion of free floating surface oil. In the very unlikely case of inadvertently spraying a bird with dispersant, there may be some short-term impact due to loss of waterproofing of feathers. However, for most birds, as well as for fur-bearing mammals, and sea turtles, the benefit of removing the oil from the surface and transferring it into the water column is likely to outweigh the minimal chance of dispersant exposure (Kucklick et al., 1997; NRC, 1989).

There may be some possibility of ingesting dispersed oil which could cause injury to the gastrointestinal tract and affect the animals' ability to absorb or digest food, damage internal organs or lead to reproductive failure or death (USFWS, 2010). However, when dispersants are applied appropriately, the concentration of dispersed oil in the water column will rapidly decrease to the point where ingestion concerns are not significant.

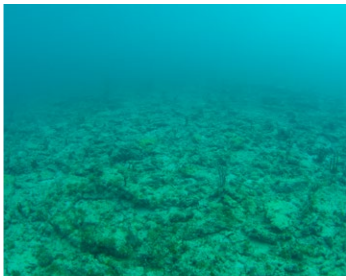
2. Water Column Resources

Water column (mid-water) resources are often the primary concern when dispersants are being considered. In general, plankton, invertebrates, and fish are thought to be at no more risk from dispersed oil compared to undispersed oil (Boyd, 2001). In one study, test results on the effects of untreated and dispersed oil on the homing mechanism of adult salmon showed no significant difference in the percentage of return or in the time it took fish to return (NRC, 1989).



Current studies support other evidence that effects are life-stage dependent. Eggs and larval forms of marine resources are more susceptible to impacts than adults (Hatlen et al., 2010; Tjeerdema et al., 2011). Exposure to dispersed oil is expected to be of short duration as dilution occurs rapidly. Additionally, population dynamics of large numbers of eggs and larval life stages support a short-lived effect with relatively rapid recovery.

3. Benthic/Bottom Dwelling Resource



In shallow-water environments, bottom dwelling organisms would be more likely to be exposed to and affected by dispersed oil than floating oil. Shallow environments are defined as being less than 33 feet (10 m) deep and fewer than three nautical miles offshore (5.6 km) (Kucklick et al., 1997). These are generally not the primary areas where dispersant use would be recommended since, in the short-term, the concentration of dispersed oil may be high enough to cause both lethal and sub-lethal effects in some benthic resources. However, studies with seagrass beds have shown them to experience no increase in effect with exposure to dispersed versus undispersed oil (NRC, 1989; Gilfillan, 1992).

4. Intertidal and Shoreline Resources

Dispersing oil offshore *before* it impacts intertidal habitats and their resident organisms is the preferred solution in most instances (NRC, 1989; IT Corp., 1993; Kucklick et al., 1997). Aquatic toxicity studies of dispersed oil on invertebrates in shallow, intertidal environments have shown that chemically dispersing the oil results in the same or less toxicity than undispersed oil alone (NRC, 1989). Dispersed oil should also pose the same or less of a risk than undispersed oil for intertidal plants, like marsh grasses, especially in the long-term. This is because exposure to the oil is reduced with the application of dispersants, which work to decrease or eliminate the layers of oil that are normally deposited by the slick each time the tide recedes.

Dispersants should typically be applied to a slick well before it reaches the shore; in many coastal regions around the world where dispersant use may be considered, dispersant applications are restricted to areas outside of a minimum distance from shore in waters of sufficient depth. In cases where oil is appropriately dispersed prior to impacting these habitats, the net ecological effect may be much less than when oil is allowed to strand (NRC, 1989; IT Corp., 1993; Kucklick et al., 1997). For more information on the Dispersant approval process in the US, refer to **Fact Sheet #7 – Dispersant Use Approvals**.

NEBA Case Study: Tropical Investigations in Coastal Systems

The TROPICS (Tropical Investigations in Coastal Systems) field study began in 1983/84 near Bocas del Toro, Panama. The study was designed to examine the relative short and long-term effects of dispersed crude oil versus non-dispersed crude oil on tropical marine ecosystems. After baseline studies (1983), two 900 m^2 sites composed of intertidal mangrove and sub-tidal seagrass-coral zones were dosed (1984) with untreated Prudhoe Bay crude oil and Prudhoe Bay crude oil dispersed with Corexit® 9527. At periodic intervals over 25 years, the sites were monitored and effects were compared to a nearby reference site.

The TROPICS field test conditions are viewed as an extreme or worst case scenario because the average water depth was less than 1 meter and concentrations of dispersed oil in the shallow water reached over 200 ppm, significantly higher than that normally observed following dispersant use in the offshore environment. The TROPICS site has been intensely monitored during the past 29 years, with 20 separate studies conducted and reported over that period. The results serve as excellent guidance for responders to spills in comparable environments, providing clear evidence of the net environmental benefit of nearshore use of dispersants in tropical ecosystems (Baca, et al., 2005).

As in the near-shore field studies discussed in the preceding section, the dispersed oil site experienced less stranding of dispersed oil on sediment and nearshore surfaces and rapid removal of dispersed oil by tidal flushing. However, oil was not removed as promptly from the untreated oil site and still remains today. The results were:

- The untreated oil had significant effects on the mangroves. Even after 10 years (Dodge, et al., 1995 reported by Lewis and Aurand, 1997), the area still contained only half the original concentration of mangrove trees.
- There was no observed direct mortality on mangroves in the areas impacted by the dispersed oil. This is probably because dispersant kept oil from attaching to the sediments and mangrove prop roots and the dispersed oil flushed out rapidly.
- Corals were visibly affected by dispersed oil but not by untreated oil. But at the 10 year mark, those that had been impacted had recovered and no significant difference existed between experimental and control sites (Dodge, et al, 1995; Lewis and Aurand, 1997).
- Sea grasses were not affected by either treatment but invertebrates around the grasses were measurably affected by dispersed oil.

FIGURE 1. Exposure of Mangroves to Oil in TROPICS Experiment

Scientists who continue to monitor the TROPICS site indicate that some of the original untreated North Slope oil is still present and occasionally seeps out, causing a low level of ongoing chronic impact (Baca, et al., 2005; DeMicco et al., 2011). One conclusion from the Panama field test is that adding dispersant to the oil going into a sensitive habitat and seeing it promptly flushed from the area is preferable to having untreated oil remain in a low-energy area with the potential for ongoing impact. As one of the recent principal investigators, Dr. Bart Baca of CSA South, Inc., has said on many occasions, protection of the habitat is more important for the ecosystem in the long term than any resulting shorter-term effects on organisms themselves. Organisms can re-populate quickly as long as the habitat is preserved.

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