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INTRODUCTION TO **DISPERSANTS**

Things You **Should Know**

Mechanical recovery will always be the most widely used response option, because most spills are small and nearshore.

Dispersants remove oil from the water surface thereby protecting birds, mammals, and sensitive shorelines.

Dispersants can be used under a broad range of environmental conditions. For large offshore spills, the limitations of other response options may make dispersants the most effective response tool.

Modern dispersants are biodegradable and contain ingredients which are similar to, and in some cases less toxic than those found in many common household soaps, cosmetics, shampoos and even food (Fact Sheet 2).

All environments contain naturally occurring microbes that feed on and break down crude oil.

Dispersants are designed to break a slick up into tiny oil droplets, which enhances the rate of microbial degradation and ultimately removes the oil from the environment.

Dispersant use is always based on a net environmental benefit analysis (Fact Sheet 6).

Scientists have been studying the effects of dispersants on the marine environment for over 30 years, and are still actively engaged in dispersant research, development and innovation.

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 tiny oil droplets in relation to their volume makes the oil much easier for the petroleum-degrading microorganisms to consume (**Figure 3**).

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 what dispersants are, how they work, when their use is considered, and any associated environmental trade-offs and potential human health effects.

Fact Sheet Series

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Introduction

Unfortunately, when an oil spill occurs adverse impacts will occur. The goal of oil spill responders is to rapidly determine which options will reduce these impacts as much as possible given the conditions of the specific incident. The main categories of response options available for marine spills include:

- On-water (surface) mechanical recovery (boats, boom, skimmers, etc.).
- Surface or subsea applications of dispersants to enhance natural microbial degradation.
- Controlled burning, known as in-situ burning (burning in place on the water surface).
- Monitor and evaluate — allowing natural processes to take place with monitoring.

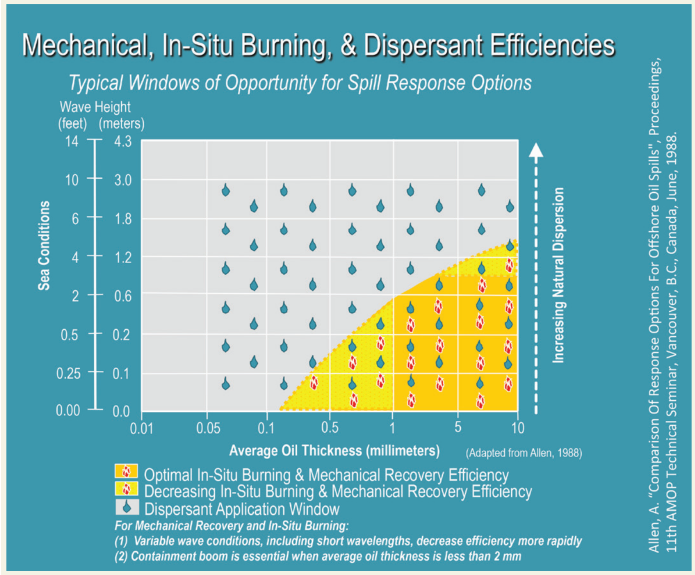
All of these options have their place in oil spill response because of the extreme variability of marine spill conditions. Mechanical recovery will generally be the most important and widely used oil spill response option because most spills are relatively small, close to shore, and often near locations where boats, boom, skimmers, and trained responders are available.

Dispersants become a critical response tool for larger spills far from shore, spills more distant from stockpiles of recovery and containment equipment, when weather and ocean conditions preclude the use of other options, or when weather conditions are predicted to become more severe. This is because in addition to vessel-based operations, dispersants can be rapidly applied from aircraft as well; they are efficient when wind and waves prevent vessel-based mechanical recovery or in-situ burning operations, and they are the only effective option when slicks have spread very thin (< 0.1 mm) (**Figure 1**).

Additionally, dispersant aircraft can typically travel to spill locations at speeds over 150 knots (170 mph; 275 kph) compared to 7 knots (8 mph; 13 kph) which is the typical speed of a response vessel transiting to a spill location. Arriving at the spill location quicker allows an effective response to start before slicks have spread, moved, or broken apart into smaller surface slicks. Additionally, aircraft are also able to travel between slicks located only a few miles apart in a matter of minutes, while vessel-based response options may require many hours to haul in the equipment, move to a new location, and redeploy the equipment.

Seas with breaking waves greater than 3-5 feet (approximately 1 to 1.5 meter) reduce the efficiency of both mechanical recovery and in-situ burning. This is because both options require containment boom to corral and contain slicks in an effort to thicken slicks for efficient operations. However, booms begin

FIGURE 1. Effectiveness limits of response options due to sea conditions and average oil thickness (Source: Coolbaugh, 2011, Modified with permission from A. Allen/Spiltec)



to lose the ability to contain oil in those conditions and become less efficient as wave heights increase, causing slicks to wash over or under booms. As depicted in **Figure 1**, potential wave-height and average oil thickness have an effect on the operating windows for the three main offshore response options.

Dispersants, however, retain their effectiveness when mixing energy in the form of waves increases, since the greater the mixing energy, the smaller the resulting dispersed oil droplets. This both reduces the potential for resurfacing of droplets (small droplets rise much more slowly) and creates additional surface for microbial degradation—tiny droplets have a greater surface area to volume ratio than larger droplets. In addition to this, larger waves cause greater mixing that helps to reduce the concentration of dispersed oil in the water column even more rapidly.

Containment boom also has limitations when attempting to collect thin oil slicks. As mentioned, oil slicks rapidly spread and become extremely thin within hours of a spill. Low-viscosity oils will eventually become as thin as 0.1 mm on average (Lehr et al., 1984) with sheen being even thinner (NOAA, 2007). Slicks and sheen this thin simply cannot be collected efficiently in boom because only a small volume of oil is encountered and collected within the boom at any time. For example, a boom with a 330 foot (100 m) opening (also known as "swath") width collects a 0.1 mm thick slick at approximately 19 m^3 per hour (120 barrels or about 5,000 gallons/hour) because vessels can only move forward at about 1 knot (1.2 mph; 2 kph) for most types of boom systems to keep the oil contained. There are boom systems that can move faster, but they do not have swath widths approaching 100 m. In contrast, a large dispersant delivery plane operates at 150 knots (170 mph; 275 kph) and has a swath width of 130 feet (40 m) allowing it to treat a 0.1 mm thick slick at a rate of approximately 525 m^3 per hour (about 3,300 bbls or 140,000 gallons/hour) which is a significant improvement of any boom system. More detail is provided in **Fact Sheet #7 – Aerial and Vessel Operations**.

Although dispersants have many operational benefits, dispersant use, as with any response option, is only justifiable when it is clear that it will provide a net environmental benefit; that is, its use does more good than harm (**Fact Sheet #6 – Assessing Dispersant Use Trade-offs**). The decision to use dispersants involves trade-offs between decreasing the risk that oil on the water's surface presents to surface animals and shoreline habitats while increasing the potential risk to organisms in the water column. Time-critical choices must be made regarding which options are best to manage potential impacts.

The goal of this Fact Sheet is to provide a clearer understanding of dispersants and the basis for their consideration in an oil spill response decision-making process.

How Dispersants Work

Dispersants generally contain surface active agents (surfactants) and solvents. Surfactants are the active ingredients in many common household products including soaps, cosmetics, detergents, shampoos, and even food (Fingas et al., 1991; 1995). Dispersants work because surfactant molecules have one end that is attracted to oil while the other end is attracted to water. They align themselves at the oil/water interface and reduce interfacial tension, thereby enhancing the breakup of a slick into tiny oil droplets (**Figure 2**). When mixing energy is applied (e.g., wind, waves, currents), the dispersant-treated oil slick will break up into many tiny droplets that are less than 100 microns in diameter (smaller than the size of a period on this page) (**Figure 3**). This means that effectively dispersed oil droplets are unlikely to ever resurface, and if they do, the next wave will likely re-transfer them into the water. When impacted by waves, untreated slicks on the water surface tend to form larger droplets that rapidly resurface and reform into a slick.

During surface applications, the tiny dispersed oil droplets

FIGURE 2. Dispersants are comprised of two parts. Dispersant molecules attract water on one end, and oil on the other. Dispersants reduce surface tension between oil and water so that oil slicks can break apart.

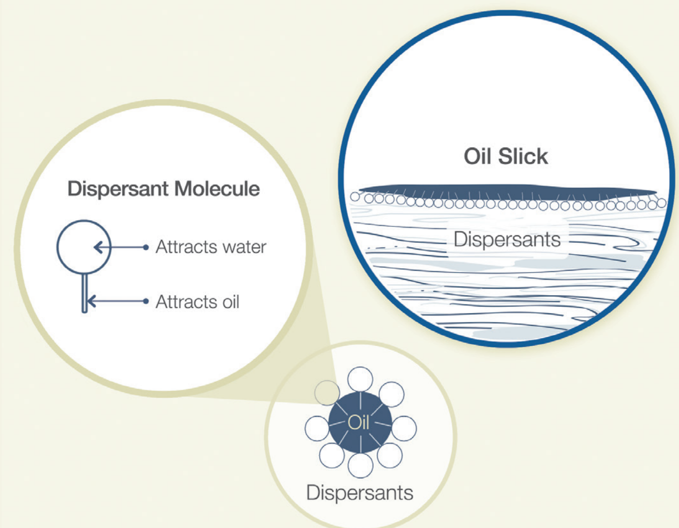
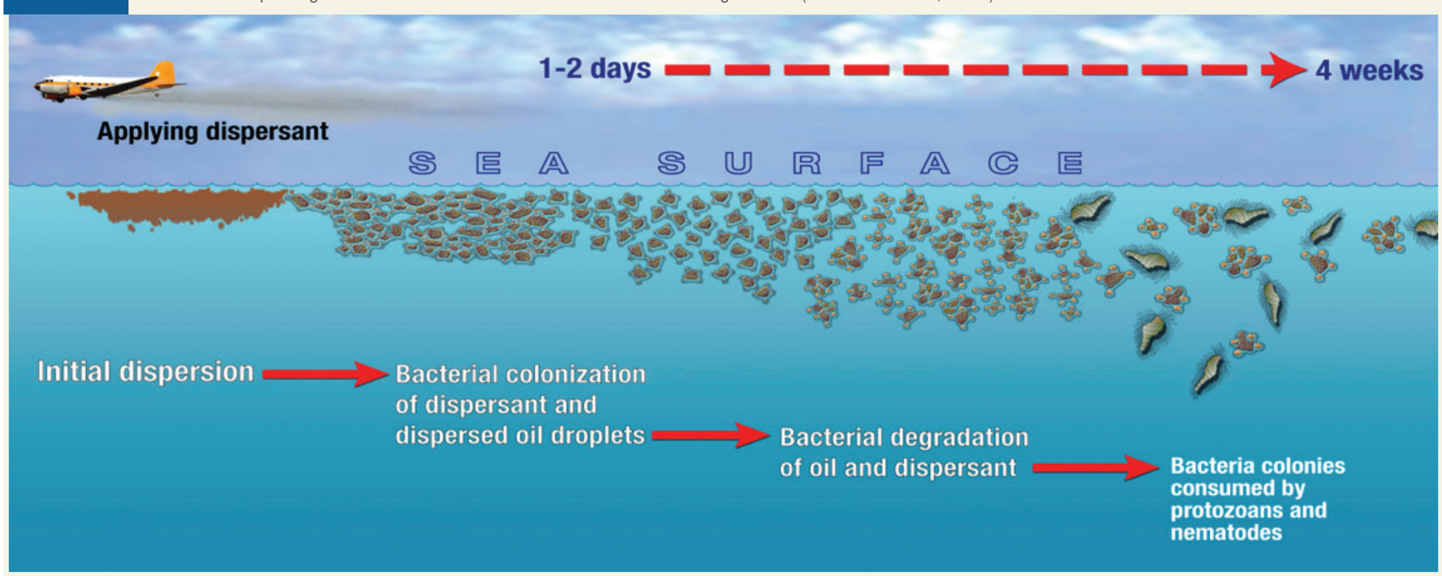


FIGURE 3. Process of dispersing oil into water column for accelerated microbial degradation (Source: Nedwed, 2011).



rapidly spread within the top 30 feet (~10 meters) of the water column and provide an easy target for microbial degradation. Oil-degrading bacteria are present everywhere in the marine environment, from the Arctic to the equator, from the sea surface to the seafloor and at all water depths in between. Thus, as mentioned above, dispersants enhance removal of oil from the environment through microbial degradation.

Dispersants work best on fresh oil that has not weathered significantly (e.g., become thicker) and are generally considered to be most effective on oils that have been on the water for less than 72-96 hours (NRC, 2005). Therefore, decision-makers must decide quickly whether to use dispersants during a spill in order for dispersant use to be the most effective. A batch (everything spilled at once) or a continuous (oil continues spilling over time) spill is also an important consideration because a continuous spill may require continuous dispersant applications.

Oils also vary in viscosity/thickness and composition and dispersants may work differently on different types. In general, the less viscous or lighter the oil is, the more easily it is dispersed. **Fact Sheet #3 – Fate of Oil and Weathering** provides more information on the types of oil and the changes oil undergoes after being spilled into the environment.

Research and experience has shown that dispersants work best on light oils and medium to heavy weight crude oils (**Table 1, Groups II and III**) (Nedwed and Coolbaugh, 2008). Dispersants can effectively disperse light products; however, these materials such as gasoline and diesel tend to rapidly evaporate and biodegrade when spilled, so the use of dispersants is not recommended. Conversely, due to the composition of very heavy oils like bunkers or asphalt-like products (**Table 1, Groups IV and V**), their components limit the dispersion action. However, research has shown that dispersants can be effective on more viscous oils and that dispersants should not be ruled out before being tested in the field with the understanding that thicker or heavier oils may disperse more slowly than light oils.

Initial elevated concentrations of tiny dispersed oil droplets will rapidly dilute and their impact will be very short-lived and localized. Field trials and wave-basin tests show that dispersed oil dilutes to concentrations below 1 ppm within hours after application of dispersants. These concentrations are below most toxicity thresholds for marine organisms that have undergone testing with constant exposures to dispersed crude oil for 48 to 96 hours. This rapid dilution explains why fish kills have never been observed in areas where there is significant water depth (10 meters or greater) after dispersants have been properly used.

The dispersed oil droplets will continue to dilute and are expected to have concentrations less than a few ppb within 2 days (Nedwed, 2011). Research indicates that microbes colonize dispersed oil droplets within 1 – 2 days (MacNaughton et al., 2003) at which point the microbial degradation process becomes rapid. By this time, the dispersed oil concentrations are too dilute to exhaust the available nutrients (primarily nitrogen and phosphorus) or available dissolved oxygen. As a result, aerobic microbial degradation proceeds much more efficiently than it would on a shoreline or in near shore sediments. In general, the components of oils that are of the most concern are typically the smaller, most soluble and volatile compounds that will tend to rapidly evaporate and dissolve. These also tend to be biodegraded first because they are easier for microbes to consume. As the oil droplets are biodegraded, they become less toxic over time.

Dispersants make it more difficult for oil droplets to stick back together or to other objects, like sediment, sand, wildlife, vegetation, rocks, or other hard surfaces in the nearshore environment. Because dispersed oil droplets do not reform

TABLE 1. Oil Type and dispersants effectivness

Group	Common Products	Specific Gravity	API	Natural Dispersion	Chemical Dispersion
I	Gasoline, Ker	< 0.8	> 45	Rapid	Not Recommended[1]
II	Diesel, Heating Oil	0.8—0.85	35—45	Moderate–Rapid	Rapid
III	Alaskan Crude Oil, Gulf of Mexico Crude Oil	0.85—0.95	17.5—35	Moderate–Slow	Rapid
IV	Heavy Fuel Oil, Venezuelan Crude Oil	0.95—1.0	10—17.5	Slow	Moderate
V	Oil Sand, Bitumen, Asphalt	> 1.0	< 10	Little or None	Not Applicable[2]

[1] As Group I oils, such as finished product gasoline evaporate rapidly, the use of dispersants is not recommended
[2] As the specific gravity of Group V products is heavier than fresh water, these oils may sink and the use of dispersants may not be applicable
Source: Nedwed and Coolbaugh, 2008

into slicks (or re-coalesce), it is unlikely that dispersed oil will have the capability to form tarballs. For more information on this topic, refer to **Fact Sheet #3 – Fate of Oil and Weathering.**

When Dispersent Use is Considered

Scientists have been studying the effects of dispersants on the marine environment for over 30 years, and are still actively engaged in dispersant research, development, and innovation. Dispersants are often considered a first response option in a number of countries around the world (ITOPF, 2010). In the US, dispersants are typically considered for offshore oil spills when surface slicks become too large for effective containment by boom, when the spill is located far from stockpiles of mechanical recovery equipment, or when the sea state prevents, or will soon prevent, the use of other response options.

One way to assess response tradeoffs is by the Net Environmental Benefit Analysis approach, also known as NEBA. NEBA is a process used to compare all response options, including natural recovery (no human intervention), with a goal to determine which combination of options can best minimize the spilled oil's overall long-term impact on resources and the environment (**Fact Sheet #6 – Assessing Dispersant Use Trade-offs**).

As already discussed, oil spilled at sea can be very dynamic – rapidly spreading to become extremely thin, moving with winds and currents, and breaking up into smaller slicks that can be separated by large distances. This dynamic nature combined with the potential for rapidly changing weather conditions means that all available response options should be considered to protect organisms, habitats, and human use areas.

In most marine environments, nearshore and shoreline areas are the most biologically rich and potentially most sensitive to oil spills. For this reason, keeping oil off of these areas is necessary to minimize environmental impacts. The use of dispersants is often the best option to help protect these sensitive areas but there are important factors to consider with the use of these materials.

Trade-offs in Decision-making

There is a general perception that the main trade-off associated with dispersant use is the protection of surface, nearshore, and shoreline resources at the expense of water column resources that otherwise would not have been impacted. Water-column organisms are not free of risk from undispersed surface slicks. Surface slicks also release the toxic components of oil into the water column, but potentially over an extended period of time. While evaporation of some oil components will reduce their level to some extent, some of these soluble components may find their way into the water column whether dispersants are used or not.

The application of dispersants serves to rapidly transfer these compounds into the water column. As a result, dilution is rapid, which tends to minimize any negative impact as scientific studies by the EPA and others have shown (BenKinney et al., 2011; Clark et al., 2001; Coelho et al., 2011; EPA online, 2011; Hemmer et al., 2010; Judson et al., 2010).

Another factor to consider regarding dispersant use is the potential negative effect that they may have if they are used in waters less than 30 feet (~10 meters) in depth. At these depths, dispersed oil droplets may not dilute as rapidly and could affect water column and bottom dwelling plant and animal communities. Dispersant use in such areas must take into account the associated trade-offs to water column species in relation to the potential benefits, such as preventing a slick from entering environmentally sensitive or economically important nearshore or shoreline areas.

Sub-lethal impacts from dispersed oil have been reported in recent studies (Whitehead, 2011) and are addressed in greater detail in **Fact Sheet #4 – Toxicity and Dispersants**.

Further, sub-lethal impacts are not limited to dispersed oil in the water column since untreated oil slicks can provide similar aquatic exposure to oil components. Further still, chronic impacts (those from long-term exposure to elevated concentrations) are more likely for untreated slicks that strand on shorelines or mix with the sediment in shallow near shore areas since they provide a potentially longer-term source of crude oil components to the near-shore areas. Appropriately applied dispersants can reduce the amount of stranded oil onshore A Net Environmental Benefit Analysis will often indicate that dispersants will provide the environment the best opportunity to recover.

Potential Human Health Effects

There are concerns about oil spills and the use of dispersants. While environmental risks have been the primary concern in the past, concerns about the potential for human health risks associated with dispersant use have recently increased. Risks to human health and community assets (e.g., beaches, shorelines, etc.) from the oil, dispersed oil, and the dispersant itself must be evaluated and communicated to all interested parties in an effective manner. It should be noted that the components of the most widely used dispersant in the U.S. (Corexit® EC9500A) were specifically chosen because they had previously been approved by the Food and Drug Administration for either human contact or consumption.

Each surfactant has alternative uses in such products as cosmetics, pharmaceuticals, and even food (Fingas et al., 1991; 1995). Further, the components of dispersants have been evaluated for bioaccumulation potential based on their persistence and the results indicate that the potential is low (Garcia et al., 2009; Prince et al., 2003). On-scene health hazard evaluations for all major offshore response activities (including dispersants) performed by the National Institute of Occupational Safety and Health (NIOSH) found that standard personal protective equipment with exposure monitoring (if deemed necessary) was adequate to protect oil spill responders (King and Gibbins, 2010; NIOSH, 2010). Dispersant use actually reduces public contact with oil by addressing it offshore and preventing oil from coming ashore. It also reduces the potential exposure of cleanup workers who could otherwise be exposed to oil and oil fumes while recovering it at sea or on the shoreline. For more information on this topic, refer to **Fact Sheet #2 — Human Health and Safety**.

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