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TOXICITY AND **DISPERSANTS**

Things You **Should Know**

Dispersants included in EPA's list of approved products have low toxicity (EPA Office of Research and Development (ORD), 2010).

Many household products are more toxic than approved dispersants.

Most substances are toxic at some level.

Oil is more toxic than dispersants.

Dispersed oil and dispersants rapidly dilute in the water to concentrations below most acute toxicity thresholds.

Because of enhanced dilution and biodegradation, dispersed oil is less likely to persist and cause chronic effects than untreated oil.

Laboratory tests are used to determine the relative toxicity of different dispersants and to help predict potential effects in the environment.

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.

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 provides an overview of aquatic toxicity testing and the potential effects that may occur when dispersants are used to respond to oil spilled on water. **Toxicity** is defined as the "inherent potential or capacity of a material to cause adverse effects in a living organism" and **Aquatic Toxicity** is the effect of chemicals, materials, and activities on aquatic organisms. The range of these effects is considered from the subcellular level, to whole organisms and even to individual communities and whole ecosystems (Rand, 1995).

Fact Sheet Series

Introduction

Large volumes of dispersants were used during the response to the Macondo Well release in the Gulf of Mexico in 2010. Approximately 1.84 million gallons (7 million liters) of dispersants were used at the surface and subsurface (Lehr et al., 2010). Prior to this, the largest use of dispersant was during the 1979 IXTOC-1 spill in the Bay of Campeche, Mexico where 1 to 2.5 million gallons (~4 to 10 million liters) of dispersants were applied over a five-month period (EPA online, 2011). With the quantities of dispersant applied during the Macondo response and for responses in the past, the government and public continue to question the impact that oil and dispersed oil may have on the environment. Scientists have studied the effects of oil, dispersants and dispersed oil on organisms in the marine environment for more than 30 years.

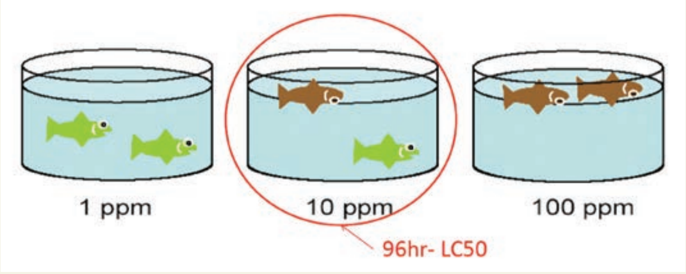
Research efforts often focus on measuring the aquatic toxicity of dispersants on standard test organisms, such as fish and shrimp (EPA ORD, 2010). Adverse effects can include changes to behavior, physiology (such as slowed movements), reproduction (such as reduced fertility), or possibly death when in the presence of certain concentrations of the test materials. Observed effects are a function of both the **duration of exposure** to the chemical and the **concentration** of the chemical during the length of the test. In the actual aquatic environment, the length of exposure varies with tides and currents and the mobility of the potentially affected organism, while the concentration of a chemical is heavily influenced by the following:

- Physical, chemical, and biological properties of the ecosystem, such as salinity, temperature, water depth, waves, and currents, which will influence vertical and horizontal mixing in the water column.
- Sources and rate of input of the chemical into the environment.
- Physical (e.g., boiling point, viscosity) and chemical (e.g., elemental composition) properties of the chemical.

Observed effects can be produced by short-term (acute) or long-term (chronic) exposure. In the case of oil spills, the potential for negative effects from short-term exposure would be expected to occur early in the spill. This is because some of the smaller, more volatile molecules in the oil are quickly lost by evaporation but also can readily dissolve into the underlying water creating short term aquatic toxicity before being diluted and degraded naturally. Alternatively, long-term exposures generally involve exposure to decreased amounts of the larger compounds found in oil that are less toxic.

The toxicity of a substance is also relative, and often, species dependent. Testing can be used to produce some basic relative categorizations about the toxicity of substances. For example, the lethal concentration to 50% of the test organisms (LC_{50}) is often used as a measure of aquatic toxicity (**Figure 1**).

FIGURE 1. Example of an LC_{50} test showing the concentration of a chemical that will kill 50 percent of the animals tested.
Source: A. Bejarano, 2012.



Measuring Toxicity

Essentially, all substances have some ability to lead to toxic or adverse effects which are directly related to concentration and length of exposure. The “adverse effects” are responses exhibited outside the normal range for healthy organisms. In an effort to understand the adverse effects of oil, dispersed oil, and the dispersant itself, the EPA and other agencies evaluate the aquatic toxicity of an exposure over a specified period of time.

NOTE:

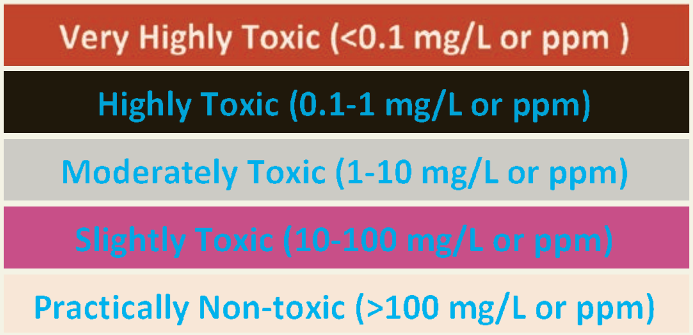
The reader is cautioned that laboratory aquatic toxicity tests are NOT representative of the likely exposures experienced by organisms in an environment that is affected by spilled oil. Natural weathering processes like spreading, evaporation, and dilution occur which serve to reduce the potential exposure duration and concentration to well below those used in toxicity tests; refer to **Fact Sheet 3 — Fate of Oil and Weathering** for more information on how oil behaves and changes over time.

A laboratory test only allows a relative comparison between the aquatic toxicity of various chemicals and is not an evaluation of potential impacts to organisms in the environment.

Toxicity tests are used to help predict the potential adverse effects of chemicals on aquatic organisms or humans. When measuring toxicity under laboratory conditions, the goal is to estimate what concentrations of a chemical cause a specific effect over a specific period of time. These may be either short-term or long-term tests. All quantitative aquatic toxicity assessments are based on the dose-response concept (typically measured in parts per million [ppm] or mg/L; and parts per billion [ppb] or µg/L). As the dose (exposure) to a chemical increases, so does the potential for a negative response. When comparing chemicals side-by-side, the *more* chemical it takes to cause an acute effect, the *less* toxic the chemical is.

The US EPA (EPA online, 2012) has established the following scale (**Figure 2**) for interpreting laboratory-generated aquatic toxicity information using LC_{50} values (mg/L = ppm).

FIGURE 2. US EPA's LC_{50} aquatic toxicity scale for laboratory-generated aquatic toxicity data. Source: EPA online, 2012.



Very Highly Toxic (<0.1 mg/L or ppm)

Highly Toxic (0.1-1 mg/L or ppm)

Moderately Toxic (1-10 mg/L or ppm)

Slightly Toxic (10-100 mg/L or ppm)

Practically Non-toxic (>100 mg/L or ppm)

The aquatic toxicity results for two key test species (mysid shrimp and silverside, a small fish also known as *Menidia*) as determined by EPA for the Macondo response are shown for the Macondo Well crude oil, the dispersant Corexit® EC9500A, and the oil-dispersant mix (**Table 1**).

Furthermore, the US EPA evaluated the eight commercially available dispersants and found that the dispersants tested had different levels of toxicity, but the major product used, Corexit® EC9500A, was among the least toxic. Ultimately, the crude oil by itself was found to be more toxic to the test species than the dispersants alone; the dispersants alone were less toxic than the dispersant-oil mixture; and the oil alone displayed toxicity results similar to the dispersant-oil mixtures (EPA ORD, 2010).

Influences on Toxicity of Oil-Dispersant Mixtures

Although tests can be used to produce a numerical measure of a substance's aquatic toxicity and provide important information about the effects of oil and dispersants, many of these tests do not accurately reproduce the different types of exposures organisms may experience during an actual oil spill. For example, when dispersants act to break up the oil into droplets, moving the now dispersed oil from the water surface downward into the water column, oil exposure will typically decrease for surface-dwelling and intertidal organisms, but increase for water column and possibly, bottom-dwelling organisms, for a period of time. In general, concentrations in the water column are expected to decrease fairly rapidly, i.e., within a matter of hours. This is different from test protocols which typically use a constant concentration over a fixed amount of time (typically 48 to 96 hours).

Any detectable or measurable response of an organism in a laboratory toxicity test should not be interpreted as resulting

TABLE 1. EPA's aquatic toxicity testing summary results for the spilled oil, dispersant, and dispersed oil from the Deepwater Horizon Response (EPA ORD, 2010).

	Louisiana Sweet Crude (LSC) Oil		**Dispersant (Corexit 9500)**		**Dispersed Oil (LSC + Corexit 9500)**	
Species Tested	**Mysid Shrimp**	***Menidia beryllina* (Fish)**	**Mysid Shrimp**	***Menidia beryllina* (Fish)**	**Mysid Shrimp**	***Menidia beryllina* (Fish)**
Very Highly Toxic						
Highly Toxic						
Moderately Toxic	**2.7** ppm	**3.5** ppm			**5.4** ppm	**7.6** ppm
Slightly Toxic			**42.0** ppm			
Practically Non-toxic				**130.0** ppm		

in a similar effect in the environment (Rand, 1995). During an actual incident, there are many factors that can change the effects that oil-dispersant mixtures may have. These factors can include:

- **Differences in length of exposure**. Length of exposure can vary greatly over time, as tides change or currents shift. Exposure may increase, decrease, or even stop. Exposure also varies between intertidal, surface and water column organisms.
- **Volume of dispersants or oil-dispersant mixtures**. Higher volumes may result in increased exposure to dispersed oil.
- **Weather**. Depending on sea state, oil-dispersant mixtures may spread out faster, deeper, further, and become more diluted quite quickly.
- **Weathering**. Changes the oil undergoes as a result of natural processes.

Laboratory tests give very conservative estimates of potential exposure effects to resources in the water column. The use of a spiked/declining dose "flow-through" toxicity test provides a more realistic means of evaluating the likely exposure of resources in the environment but it is not the normal procedure for most studies (ASTM, 2007a & 2007b; Rand, 1995).

Toxicity of Dispersants and Oil-Dispersant Mixtures

There are many complicating factors in the measurement and prediction of toxicity related to specific spill conditions. Many studies have evaluated the aquatic toxicity of crude oils, dispersants, and oil-dispersant mixtures. These studies indicate that dispersants are less toxic than oil itself (EPA ORD, 2010; NRC, 2005).

However, dispersants do increase the local concentration of oil in the water column for a period of time. This does not alter the toxicity of the oil, however, the potential exposure is increased for resources in the water column, at least until mixing and natural dilution occur and reduce the concentration. Potential toxicity of dispersants to humans is just as difficult to determine, especially when it is known that each dispersant formulation is composed of a different group of chemicals. However, public exposure along shorelines is unlikely, since dispersants are generally only applied more than three miles from shore by boats and planes using specialized equipment. For more information on the potential toxicity to humans (responders and the public) refer to **Fact Sheet #2 — Dispersants — Human Health and Safety**.

In summary, there is public and regulatory concern about the toxicity of the dispersant in conjunction with the oil itself in the environment. This fact sheet indicates that concern is often unwarranted as research has shown that it is the oil that is the toxic component in the exposure. Although dispersants may locally increase the oil concentration in the water column for a period of time, the large dilution potential where dispersants would be applied serves to lower the overall oil exposure duration experienced by water column organisms.

Lastly, using a Net Environmental Benefit Analysis (NEBA) approach, it is important to compare such impacts to water column organisms with those impacts to surface animals and shoreline habitats that would occur if the oil were not dispersed but remained on the water's surface. For more information on this approach, refer to **Fact Sheet #6 — Assessing Dispersant Use Trade-offs**.

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