



OIL SPILL SCIENCE

SEA GRANT PROGRAMS OF THE GULF OF MEXICO

THE SEA GRANT and GOMRI PARTNERSHIP

The mission of Sea Grant is to enhance the practical use and conservation of coastal, marine and Great Lakes resources in order to create a sustainable economy and environment. There are 33 university-based Sea Grant programs throughout the coastal U.S. These programs are primarily supported by the National Oceanic and Atmospheric Administration and the states in which the programs are located.

In the immediate aftermath of the Deepwater Horizon spill, BP committed \$500 million over a 10-year period to create the Gulf of Mexico Research Initiative, or GoMRI. It is an independent research program that studies the effect of hydrocarbon releases on the environment and public health, as well as develops improved spill mitigation, oil detection, characterization and remediation technologies. GoMRI is led by an independent and academic 20-member research board.

The Sea Grant oil spill science outreach team identifies the best available science from projects funded by GoMRI and others, and only shares peer-reviewed research results.



<http://gulfseagrant.org>



<http://gulfresearchinitiative.org>

CHEMICAL DISPERSANTS AND THEIR ROLE IN OIL SPILL RESPONSE

Larissa J. Graham, Christine Hale, Emily Maung-Douglass, Stephen Sempier, LaDon Swann, and Monica Wilson

Nearly two million gallons of dispersants were used at the water's surface and a mile below the surface to combat oil during the Deepwater Horizon oil spill. Many Gulf Coast residents have questions about why dispersants were used, how they were used, and what impacts dispersants could have on people and the environment.



The Deepwater Horizon site (NOAA photo)

On April 20, 2010, an explosion on the Deepwater Horizon oil rig killed 11 people. The rig was located 42 miles southeast of Venice, Louisiana. The ruptured wellhead had released an estimated 4.9 million barrels of Louisiana sweet crude oil before responders capped it on July 19, 2010. Some of this oil was collected at the site of the wellhead. Scientists estimate that the remainder of the oil, or about 4.1

million barrels (172 million gallons), were released into Gulf of Mexico waters.^{1,2,3,4,5}

Emergency responders attempted to clean up the oil and prevent it from reaching the shoreline by skimming and burning the oil at the surface. They also applied nearly two million gallons of **dispersants** to break up the oil. This spill was the largest application of dispersants in U.S. history.⁴

HOW DID RESPONDERS USE DISPERSANTS DURING THE DEEPWATER HORIZON OIL SPILL?

Responders used two types of dispersants, **Corexit 9500A** and **Corexit 9527A**, during the Deepwater Horizon oil spill. Both are on the federal guideline list of dispersants that can be used during a spill. Responders first applied Corexit 9527A until they exhausted the supply. Then they switched to Corexit 9500A and continued using it throughout the cleanup efforts.^{4,6} There are many different Corexit formulas and product types. When we use the word “Corexit” in this publication, we are referring to Corexit 9527A and 9500A.

During the spill, responders sprayed approximately one million gallons of dispersants over close to 300 square miles of oiled surface waters (Figure 1).^{1,4} Responders spraying dispersant from airplanes could not apply them within 2.3 miles of any vessel, within 3.45 miles of the shoreline or visible marine life, or in areas with water depths less than 33 feet deep.⁴ Responders

sprayed dispersants from boats in areas close to the wellsite where crews were working. According to the U.S. Coast Guard, this method reduced the amount of dispersant in the air, increasing the safety of the working environment. The same U.S. Coast Guard report states that emergency responders applied 98 percent of the dispersants more than 11 miles offshore.⁴

For the first time in U.S. history, responders used dispersants at very deep depths. They applied approximately 771,000 gallons of Corexit 9500A nearly one mile beneath the sea surface at the source of the leak. They did this using a remotely operating vehicle to inject dispersant at the site of the wellhead.^{1,4}

HOW DO DISPERSANTS BREAK UP OIL?

A typical commercial dispersant contains solvents and **surfactants**. Solvents help keep the chemicals mixed and help them dissolve into the oil. Surfactants allow oil and water to mix easily.

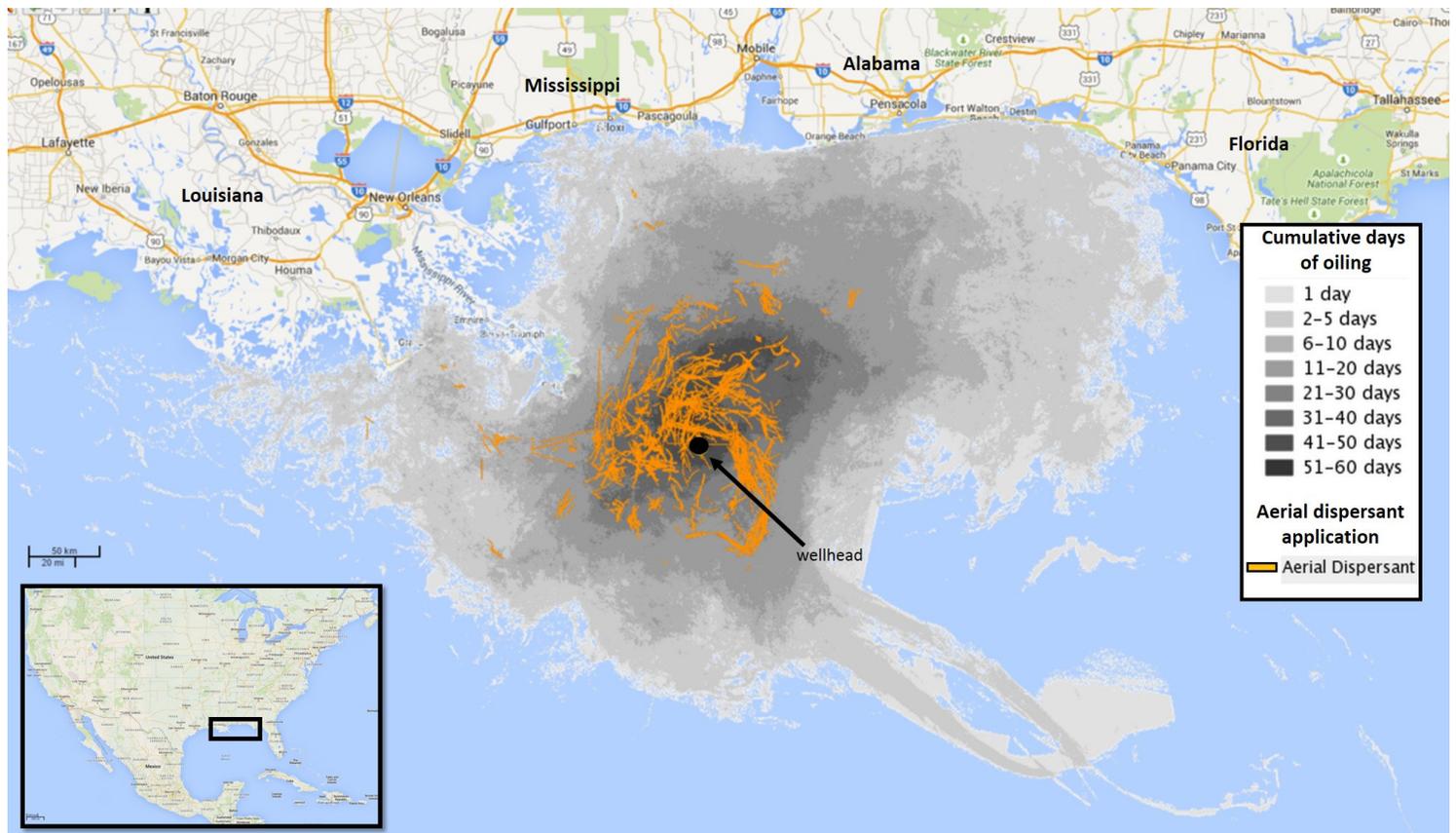


FIGURE 1. This map shows the number of days that an area was oiled during the Deepwater Horizon oil spill. Responders found oil in areas that are shown in dark gray more days than those shown in light gray. In response to the oiling, responders applied dispersants to surface water. The orange lines represent where dispersant was sprayed using airplanes. Responders also sprayed dispersant from boats close to the wellhead and at subsurface depths (not shown on this map). (Environmental Response Management Application)

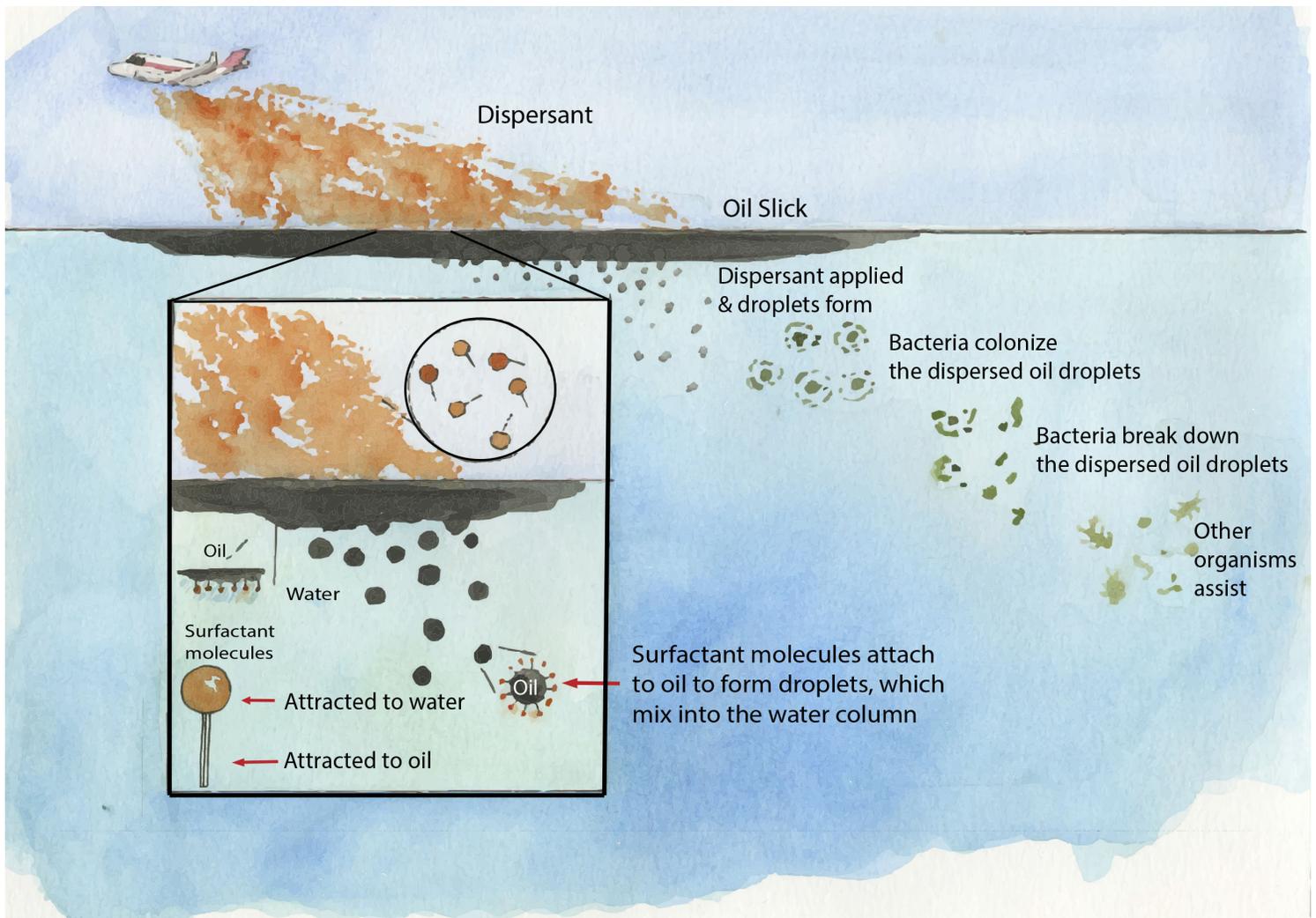


FIGURE 2. Dispersants, which are one strategy used to respond to an oil spill, contain molecules that have one end that is attracted to water and one end that is attracted to oil. When responders apply dispersants to an oil slick, these molecules attach to the oil, allowing the oil slick to be broken up into smaller oil droplets. These smaller droplets then mix into the water column and where they are “eaten” and further degraded (broken down) by microbes and other organisms. (Florida Sea Grant/Anna Hinkeldey)

By allowing oil and water to mix, the oil slick breaks into many smaller oil droplets. The smaller droplets mix into the water column and then are eventually carried away by currents, attach to particles in the water column and settle to the bottom, or evaporate.⁷ Nature’s “oil-eating” **microbes** are found in our oceans and have adapted over time to use most of the chemicals in oil as food. In the process, they naturally remove oil from the environment. Smaller oil droplets are more available to these “oil-eating” microbes than large oil slicks (Figure 2).

WHEN DO RESPONDERS USE DISPERSANTS TO CLEAN UP OIL?

Responders consider trade-offs when determining the most effective cleanup method(s) that should be used during an oil spill.^{7,8} Applying dispersants was just one of

many strategies that emergency responders used at the Deepwater Horizon site during the spill. Other response activities included burning the oil at the water surface and mechanically recovering it using skimmers or other equipment.

Emergency responders may use dispersants when other cleanup methods may not be as practical. For example, the spill is very large, the water may be too rough for other methods, or the spill may be too far away from land to use mechanical recovery equipment.⁷ Under these conditions, responders may choose to apply dispersants to break up an oil slick. They may also choose to use dispersants because they can be deployed rapidly by aircraft, cutting down on the response time.⁸

Dispersants and other response methods can prevent an oil slick from reaching the shoreline. This can reduce the

Controlled burning (left) and skimming (right) are two response techniques used to remove oil from the water surface after an oil spill. (NOAA photos)



oiling of coastal wildlife and sensitive habitats, such as coastal wetlands, mangroves, and beaches. Once these habitats are oiled, they are very difficult to clean without causing further damage to the area.⁸

However, dispersants are not always effective. When oil is dispersed, it is removed from the water's surface and harder to clean up mechanically.⁸ Dispersants may not work well on some types of oil and spraying them on patchy oil slicks can be inefficient.^{7,8} They also do not work well under very windy conditions because they can drift in the wind during application or waves can wash them off the slick. When this happens, the dispersant cannot penetrate, mix with, and break down the oil.⁷

Applying dispersants beneath the water's surface, at the site of the wellhead, was a new technique used during the Deepwater Horizon oil spill. One reason that this method was approved was related to the health of response workers and the ease of application. Deep sea application would minimize human contact with dispersants and could also occur at night and during foul weather. This technique may have been more effective at dispersing the oil because Corexit was injected right into the wellhead. This also allowed for a quicker response time because dispersants could be applied at night and in foul weather.¹

HOW DID AGENCIES REGULATE AND MONITOR DISPERSANT USE?

The **National Contingency Plan (NCP)** establishes the framework to authorize dispersant use. This plan

outlines which dispersants emergency responders can apply during a spill and how dispersant use will be monitored.⁹

Emergency responders use **Special Monitoring of Applied Response Technologies (SMART)** guidelines to monitor surface dispersant use. SMART guidelines do not look at the effects or impacts of dispersed oil. Instead, they provide information about how to apply dispersants and how well they are working.¹⁰

Responders use the SMART monitoring program to determine if dispersants are effectively breaking up oil and, if so, how quickly.⁴ The U.S. Coast Guard, National Oceanic and Atmospheric Administration (NOAA), U.S. Environmental Protection Agency (EPA), U.S. Centers for Disease Control and Prevention, and the U.S. Bureau of Safety and Environmental Enforcement were all part of developing this program.⁴ During the Deepwater Horizon oil spill, trained observers flew over the oil slick to see if the dispersant was working to break up the oil. Sampling teams collected water samples to measure the amount of dispersed oil in the water column. Agencies used this information to modify how they were applying the dispersant.⁴

In 2010, the U.S. EPA collected air samples off the coast of Louisiana for four days after the aerial application of dispersants. They tested the air for two chemicals, 2-butoxyethanol and propylene glycol. Scientists took samples 30 minutes after dispersant application and did

HOW MUCH IS TOO MUCH?

How a substance can affect you will depend on how harmful it is and how long and how often you are exposed to it. Every substance is poisonous at some level. Take water, for example. Although we need water to survive, drinking too much water can also kill us because it dilutes the concentrations of other nutrients that our body needs to function. Researchers determine how much of a substance is “toxic” by exposing animals to different doses of a chemical for varying amounts of time. Scientists have conducted most of the tests on small fish or shrimp to determine how harmful chemicals found in dispersants are to animals. It is important to note that the toxicity of a chemical will vary among different species, differing lengths of exposure time, and the other factors that might be affecting that species at the time.

<i>Dispersant used during the Deepwater Horizon oil spill</i>	<i>Potential health effects to humans based on animal tests</i>
<i>Corexit 9500A</i>	Repeated or prolonged exposure may cause eye and skin irritation, dry the skin leading to discomfort and dermatitis, or irritate the respiratory tract.
<i>Corexit 9527A</i>	May be harmful if swallowed, effect the liver and kidney, and/or damage or irritate the gastro-intestinal tract. Harmful if absorbed through skin or by inhalation. Repeated or prolonged exposure may irritate the respiratory tract or existing skin condition. Excessive exposure may cause central nervous system effects, nausea, vomiting, anesthetic, or narcotic effects.

TABLE 1. *The potential health effects of the two dispersants that emergency responders used during the Deepwater Horizon oil spill are shown above. This information was compiled from the Material Safety Data Sheets for each chemical.*

not find either chemical.¹¹ The U.S. EPA also collected onshore air quality samples along shoreline sites in Louisiana, Mississippi, Alabama, and Florida. They tested these samples for two dispersant chemicals that were most likely to be in the air in measurable amounts after spraying, 2-butoxyethanol and dipropylene glycol monobutyl ether. They found low levels of both chemicals in the air, but all were below levels that are likely to cause negative health effects. All of the data from these monitoring efforts are available on U.S. EPA’s website at <http://www.epa.gov/bpspill/dispersant-air-sampling.html>.¹²

According to the U.S. Coast Guard’s [On-Scene Coordinator Report](#), the U.S. EPA and the U.S. Coast Guard were satisfied with how dispersants were used during the Deepwater Horizon oil spill. These agencies stated that dispersants had been an important tool for reducing the oil spill’s impact and had prevented more damage to marshes, wetlands, beaches, and coast’s economy. They also stated that the information collected during the spill supported continued application of dispersants.⁴

CAN DISPERSANTS HARM MARINE ANIMALS?

The dispersants that emergency responders use today are less harmful to the environment than the more toxic products used prior to 1970.⁷ However, they still contain chemicals that can have a negative impact on aquatic life (Tables 1 & 2).

The U.S. EPA was concerned that dispersants could hurt aquatic wildlife and so, in May 2010, they directed BP to scale back on the use of dispersants. To understand how dispersants could affect aquatic wildlife, the U.S. EPA conducted independent toxicity studies in the laboratory.⁶

The U.S. EPA tested eight approved dispersants, including Corexit 9500A, on two aquatic species: Gulf mysid, a small shrimp, and the inland silverside, a fish that resides in coastal waters in the Gulf of Mexico.⁶ These laboratory tests looked at the **acute toxicity** of dispersants. Determining the acute toxicity of a substance can help scientists determine the lethal concentration. However, knowing the acute toxicity

does not help scientists understand the effects that the substance can have on the reproduction, growth, or development of an animal. Corexit 9527A was not tested during these studies because the dispersant was no longer being used in response efforts.

The laboratory experiments showed that none of the dispersants, when tested alone, were more toxic to the shrimp or silversides than oil. Corexit 9500A and another dispersant (JD-2000) were less toxic to silversides than the other dispersants that were tested.⁶

The U.S. EPA was also concerned about how oil mixed with dispersant could affect aquatic life. They conducted additional studies and found that Corexit 9500A, when mixed with oil, had similar toxicity as the seven other dispersants that were tested.⁶ Oil alone and oil mixed with each of the dispersants that were tested had similar toxicity to shrimp, except when oil was mixed with one of the dispersant tested (Nokomis 3-AA). The combination

The On-Scene Coordinator Report

This report documents the response efforts during the Deepwater Horizon oil spill. It provides a timeline of the spill and the efforts to address the potential impacts to public health related to the spill. This report is available at http://masgc.org/assets/uploads/publications/873/2_coordinator_report_dwh.pdf.

of oil and this type of dispersant was more toxic to the shrimp than oil alone.⁶

The extent of damage that dispersants, dispersed oil, and oil can have on aquatic life is still under debate. Some peer-reviewed research studies have found dispersants to be less toxic than oil alone, and other studies have shown that dispersants or oil plus dispersant are more toxic than oil alone.⁷



A member of U.S. Coast Guard National Strike Force on an overflight mission, observing an airplane spraying dispersant. (NOAA photo)

WHAT STUDIES ARE STILL ONGOING?

Many questions remain about the impacts of dispersants and dispersed oil on the ecosystem, environment, and human health. The Gulf of Mexico Research Initiative (GoMRI) and other research programs are looking

at alternative dispersant use and technology, how dispersants react with oil under various conditions, the environmental impacts of dispersants, and the impacts that dispersants have on human health.

CAS #	Chemicals in Corexit 9500A and Corexit 9527A	Other substances that contain this chemical ^{a,b,c}	Potential health effects to humans based on animal tests ^d
577-11-7	Di(2-ethylhexyl) sodium sulfosuccinate (DOSS)	Certain cosmetics, gelatin, chocolate powder, beverages, laxatives	Causes eye, skin, and respiratory tract irritation. May be harmful if absorbed through the skin or inhaled. Harmful if swallowed. May cause gastrointestinal irritation with nausea, vomiting, and diarrhea.
111-76-2	2-Butoxyethanol (Found in Corexit 9527A only, not Corexit 9500A)	Certain cleaners, soaps, cosmetics, lacquers, paints	Causes eye and skin irritation. May be toxic to blood, kidneys, liver, and central nervous system. Repeated or prolonged exposure to the substance can produce target organs damage, including injury to red blood cells, kidney or the liver. May cause adverse reproductive effects, birth defects, or cancer. Severe over-exposure can result in death.
57-55-6	Propylene glycol	Cosmetics, preservatives in food, medicines	Causes mild eye, skin, respiratory, and gastrointestinal irritation. May affect the behavior or central nervous system, brain, metabolism, blood, respiration, cardiovascular system, endocrine system, urinary system, and liver. Prolonged or repeated inhalation may affect behavior, central nervous system, and spleen. May be toxic to central nervous system. May mutate genetic material or cause adverse reproductive effects and birth defects.
64742-47-8	Distillates, petroleum, hydrotreated light	Cleaners, paints, varnishes	Causes skin irritation. Repeated skin contact has resulted in irritation and skin cancer in animals. May cause drowsiness or dizziness. May be fatal if swallowed or enters airways.
29911-28-2	Dipropylene glycol monobutyl ether	Cleaners, degreasers, paints	The chemical, physical, and toxicological properties of this chemical have not been thoroughly investigated.
1338-43-8	Sorbitan, mono-(9Z)-9-octadecenoate	Skin cream, air freshener	Not classified as a hazardous substance or mixture.
9005-65-6	Sorbitan, mono-(9Z)-9-octadecenoate, poly(oxy-1,2-ethanediyl) derivatives	Baby bath, mouth wash, face lotion	Not classified as a hazardous substance or mixture.
9005-70-3	Sorbitan, tri-(9Z)-9-octadecenoate, poly(oxy-1,2-ethanediyl) derivatives	Insect spray, food additive	Not classified as a hazardous substance or mixture.

TABLE 2. The chemicals that are found in Corexit 9500A and 9527A, the two dispersants that were used during the Deepwater Horizon oil spill.¹³ The Chemical Abstracts Service number (CAS) or unique identifier for each chemical substance, toxicity level based on tests on animal subjects, and the potential health effects are listed for each chemical. This information was provided by the **Food and Drug Administration** (a), **U.S. Department of Health and Human Services** (b), **Agency for Toxic Substances and Diseases Registration** (c), and **Material Safety Data Sheets** (d).

More information about these ongoing studies can be found on GoMRI's website at <http://gulfresearchinitiative.org>. Other publications focusing on dispersants are on the Sea Grant Oil Spill Science Outreach website at www.gulfseagrant.org/oilspilloutreach.

REFERENCES

1. National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling. (2010). The Use of Surface and Subsea Dispersants During the BP Deepwater Horizon Oil Spill, Staff Working Paper No. 4. Retrieved November 23, 2015, from <http://oscaction.org/resource-center/staff-papers/>
2. Griffiths, S. K. (2012). Oil Release from Macondo Well MC252 Following the Deepwater Horizon Accident. *Environmental Science and Technology*, 46, 5616-5622.
3. Coastal Response Research Center, Research Planning Incorporated, and National Oceanic Atmospheric Administration. (2012). *The Future of Dispersant Use in Oil Spill Response Initiative*. Retrieved October 10, 2014, from http://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/dispersant_future_11/Dispersant_Initiative_FINALREPORT.pdf
4. US Coast Guard. (2011). *On Scene Coordinator Report Deepwater Horizon Oil Spill: Submitted to the National Response Team, September 2011*. Retrieved October 10, 2014, from https://www.uscg.mil/foia/docs/DWH/FOSC_DWH_Report.pdf
5. Lehr, B., Bristol, S., & Possolo, A. (2010). Oil Budget Calculator Deepwater Horizon. Technical documentation: A report to the National Incident Command. Retrieved August 13, 2015, from http://www.restorethegulf.gov/sites/default/files/documents/pdf/OilBudgetCalc_Full_HQ-Print_111110.pdf
6. US Environmental Protection Agency. (2014). EPA's Toxicity Testing of Dispersants. Retrieved October 10, 2014, from www.epa.gov/bpspill/dispersants-testing.html
7. National Research Council of the National Academies. (2005). *Understanding Oil Spill Dispersants: Efficacy and Effects*. Washington, D.C.: The National Academies Press.
8. Coolbaugh, T., & McElroy, A. (2013). Dispersant Efficacy and Effectiveness. Retrieved from University of New Hampshire Coastal Response Research Center and Center for Spills in the Environment Web site: http://crrc.unh.edu/sites/crrc.unh.edu/files/media/docs/Workshops/dispersant_forum_13/Dispersant_efficacy_effectiveness.pdf
9. US Environmental Protection Agency. (1994). National Oil and Hazardous Substances Pollution Contingency Plan. Retrieved October 10, 2014, from <http://www.gpo.gov/fdsys/pkg/CFR-2011-title40-vol28/pdf/CFR-2011-title40-vol28-part300.pdf>
10. US Coast Guard, National Oceanic Atmospheric Administration, US Environmental Protection Agency, Centers for Disease Control and Prevention, & Minerals Management Services. (2006) Special Monitoring of Applied Response Technologies. Retrieved October 10, 2014, from http://response.restoration.noaa.gov/sites/default/files/SMART_protocol.pdf
11. US Environmental Protection Agency. (2014). Offshore air sampling for dispersant-related compounds. Retrieved October 13, 2014, from <http://www.epa.gov/bpspill/dispersant-air-sampling.html>
12. US Environmental Protection Agency. (2014). Mobile Air Monitoring on the Gulf Coast: TAGA Buses. Retrieved October 13, 2014, from <http://www.epa.gov/bpspill/taga.html>
13. US Environmental Protection Agency. (2015). Questions and answers on dispersants. Retrieved November 20, 2015, from <http://archive.epa.gov/bpspill/web/html/dispersants-qanda.html>

GLOSSARY

Acute toxicity - Adverse (negative) effects after an organism is exposed to one or more doses of a substance over a short time period (often, less than 72 hours).

Corexit 9527A and 9500A - dispersants approved for use in US waters and those that were used to minimize the presence of surface oil slicks during the Deepwater Horizon oil spill.

Dispersants - chemicals that are used during oil spill response efforts to break up oil slicks and can limit floating oil from impacting sensitive ecosystems such as coastal habitats.

Microbes - very tiny organisms including bacteria, fungi, archaea, and protists. Some microbes (bacteria and archaea) are the oldest form of life on earth.

National Contingency Plan (NCP) - a federal document that outlines response efforts for oil spills and other hazardous substance spills.

Special Monitoring of Applied Response Technologies (SMART) - a cooperative monitoring program that is used during oil spill response efforts to determine if dispersant application is effective.

Surfactants - compounds that work to break up oil. Dispersants contain surfactants that break the oil slick into smaller droplets that can more easily mix into the water column.

SUGGESTED CITATION

Graham, L., Hale, C., Maung-Douglass, E., Sempier, S., Swann, L., and Wilson, M. (2016). Oil Spill Science: Chemical dispersants and their role in oil spill response. MASGP-15-015.

OIL SPILL SCIENCE OUTREACH TEAM

Christine Hale

Texas Sea Grant
chris.hale@tamu.edu

Larissa Graham

Mississippi-Alabama Sea Grant
larissa.graham@auburn.edu

Emily Maung-Douglass

Louisiana Sea Grant
edouglass@lsu.edu

Stephen Sempier

Mississippi-Alabama Sea Grant
stephen.sempier@usm.edu

LaDon Swann

Mississippi-Alabama Sea Grant
swannld@auburn.edu

Monica Wilson

UF/IFAS Florida Sea Grant
Extension
monicawilson447@ufl.edu



This work was made possible in part by a grant from The Gulf of Mexico Research Initiative, and in part by the Sea Grant programs of Texas, Louisiana, Florida and Mississippi-Alabama. The statements, findings, conclusions and recommendations do not necessarily reflect the views of these organizations.