



Earth Gauge

A National Environmental Education Foundation Program

## Gulf Oil Spill Series: Biodegradation of Oil

Earth Gauge's Gulf Oil Spill series focuses on unique topics related to the Gulf of Mexico and the effects of the 2010 oil spill. All fact sheets, images and videos are freely available for use on-air and are available online at <http://www.earthgauge.net/2010/gulf-oil-spill-resources>.



Biodegradation at work in a compost heap.  
Courtesy of EPA.

### BIODEGRADATION: MICROBES AT WORK

A *microscopic organism*, also known as a *microorganism* or *microbe*, is too small to see with the human eye. The world of microbes includes protists, bacteria, fungi and some species of animals and plants.

In time, any organic material – a substance that contains carbon atoms – can be chemically broken down by microbes and invertebrates in the environment. This process is called *biodegradation*. On land, an example is compost, in which fungi, bacteria and insects decompose food waste.

Microbes use carbon for energy. For some microbes, this is an *aerobic* process (using oxygen). For others, it is *anaerobic* (without oxygen). In addition to carbon and oxygen, microbes need other nutrients and minerals to survive, such as nitrogen, phosphorus and iron.

### IN THE OCEAN

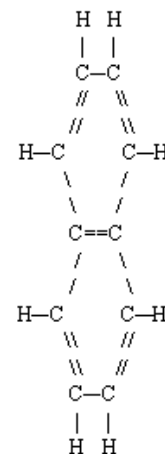
Annually, 63 natural seeps release more than 20 million gallons of oil into the Gulf of Mexico. The Deepwater Horizon spill released more than 211 million gallons of light, sweet crude oil ("light" refers to relatively few impurities and lower density than "heavy" oil; "sweet" oil is lower in sulfur than "sour" oil) into the Gulf. An estimated 25 percent of this was burned or collected, leaving much of the rest to microbes.

In saltwater ecosystems, bacteria are the dominant oil-degrading microbes. Oil is made up of *hydrocarbons*: organic compounds comprised of hydrogen and carbon (see image at right). While some hydrocarbons evaporate from or form "mousse" and tar balls on the ocean surface, hydrocarbons in the deep sea, whether released by human-caused spills or natural seeps, are eliminated almost entirely by bacteria. In June, 2010 a deep sea plume was measured in the Gulf at a depth of approximately 4,000 feet.

Over time, specialized microbes in deep water have adapted to the presence of hydrocarbons, including *polycyclic aromatic hydrocarbons* (PAHs, the most toxic types) like benzene, toluene and naphthalene. They have gained the ability to metabolize them. PAHs are known carcinogens and neurotoxins to humans and animals, and they can cause additional health problems. Some hydrocarbons are toxic to bacteria, while others are not. Some marine bacteria species, including some in the genus\* *Vibrio*, depend on oil; hydrocarbons from oil are their only source of carbon.

The presence of oil, especially from a large spill, changes the makeup of the marine microbial community. The populations of oil-tolerant and oil-thriving species increase during and immediately after an oil spill, while populations of oil-sensitive species decrease. In a study in May and June of 2010, 62 phyla\* of microbes were found.

\*In biology, organisms are categorized according to similar characteristics. *Phylum* (plural *phyla*) is one type of category, between *kingdom* and *class*. *Genus* is a more specific category. It is one category higher than *species*; similar species are grouped together in a genus.



Naphthalene (C<sub>10</sub>H<sub>8</sub>) is an example of an aromatic hydrocarbon found in petroleum. An *aromatic ring* consists of six carbon atoms.  
Courtesy of OSHA.gov.

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## LIMITING FACTORS

The rate and extent of microbial biodegradation of oil are dependent on several factors.

**Temperature:** Water temperature affects the physical and chemical properties of oil and the rate of biodegradation. Colder temperatures slow the rate; warmer temperatures increase the rate. The temperature at the Deepwater Horizon wellhead (on the ocean floor) is about 40 degrees Fahrenheit. At that temperature, the half life of hydrocarbons – the time it takes for half of the amount to biodegrade or “disappear” – is several days.

**Oxygen:** In open water, oil hydrocarbons undergo aerobic biodegradation by bacteria that use oxygen dissolved in the water. Scientists have monitored dissolved oxygen levels around the spill since it occurred. Early measurements of the deep plume showed a rate of 30 percent oxygen depletion, which demonstrated the presence of biodegrading microbes. Sediment on the ocean floor and along the coast is, for the most part, *anoxic*: it does not contain oxygen. Hydrocarbons that settle into sediments on the ocean floor and along coasts undergo anaerobic biodegradation, a much slower process. Therefore, onshore oil lingers longer than oil at sea and can become a chronic pollutant.

**Nutrients:** In addition to carbon and oxygen, bacteria need nitrogen and phosphorus to survive. These nutrients are found naturally in the ocean environment. Nitrogen and phosphorus-based fertilizers from farms and gardens on land also enter Gulf waters through stormwater runoff.

**Characteristics of Oil:** The type of oil, its concentration and the types of hydrocarbons it contains influence the rate of biodegradation. The Gulf spill released light, sweet crude oil, which is more readily broken down than heavy, sour oil. “Mousse,” tar balls or oil slicks that wash onshore are highly concentrated compared to dispersed oil, more protected from wind and wave action than oil in open water and have less surface area for microbes to access. Smaller droplets of oil are more biodegradable.



Mississippi River delta. Courtesy of NOAA.

**Prior Exposure:** Microbes adapt to gradual exposure to oil. The more oil a microbial community has been exposed to in the past, the greater its capacity and availability to biodegrade oil in the future. In one study, microbes from sediments previously contaminated with oil were able to metabolize oil 10 to 400 times faster than those from sediments that had never been contaminated. Once a species of bacteria is exposed to oil and metabolizes it, the next generations inherit that ability, a concept known as *genetic adaptation*. This has been studied in a particular species of *Vibrio* in the northwestern Gulf of Mexico.

**Dispersants:** Biodegradation occurs more readily when oil droplets are dispersed. Chemical dispersants break oil into smaller droplets, which increases the surface area available for bacteria to access. The exact effects of dispersants such as Corexit on the rate of biodegradation are unknown, especially in deep water. The effectiveness of dispersants also depends on the type and consistency of oil and the oil-dispersant ratio.

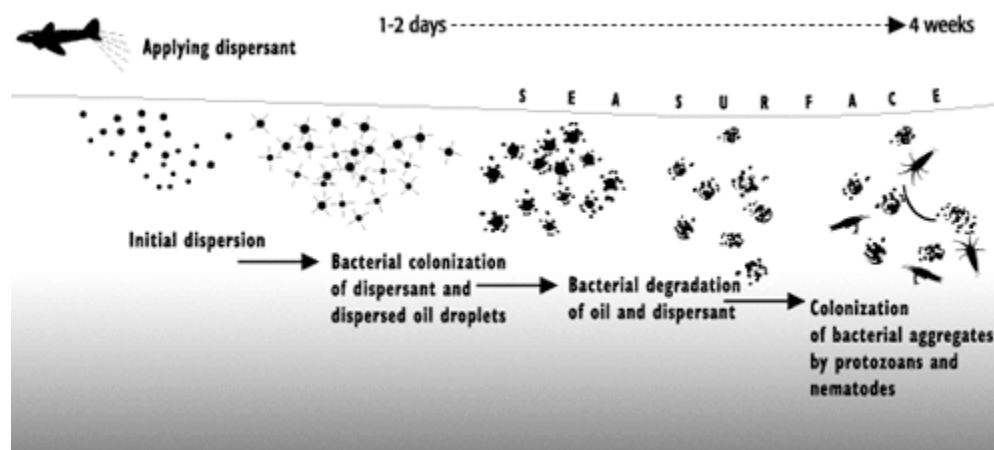


Image courtesy of NOAA Office of Response and Restoration

## In the Gulf

Several factors have influenced (and may still be influencing) the biodegradation rate of the Gulf's deep sea oil plume:

- An average temperature of about 40 degrees Fahrenheit;
- The light consistency of the oil;
- The use of dispersants, which broke the oil down into smaller particles;
- The low concentration of oil in the deep sea plume; and
- The presence of microbes that were used to metabolizing hydrocarbons from natural seeps.

## BIOREMEDIATION: SEEDING THE SEA

*Bioremediation* refers to the use of microbes or plants to return an environment to its original condition. In the case of oil spills, it is usually used along shorelines and in coastal wetlands. Bioremediation can be accomplished naturally by native bacteria or artificially by scientists. One method is fertilizing water, wetlands or beaches with nitrogen, phosphorus and iron to spur the growth of native microbe communities. This can increase the rate of biodegradation.

### **Profile: The Exxon Valdez**

The Exxon Valdez oil spill in 1989 left more than 11 million gallons of oil in Prince William Sound, Alaska. Because of the Sound's cold temperatures and low concentrations of oxygen and nutrients, scientists fertilized the water with nitrogen, phosphorus and iron, which increased the rate of biodegradation three to five times. After several years, the rate decreased to nearly minimal amounts. An estimated 20,000 gallons still remain in the Sound's sediment and rocks.

Another technique is *seeding*: introducing natural or genetically engineered bacteria that are known to degrade the type of oil that has been released. Introduced microbes have the potential to increase the extent, rate or both extent and rate of biodegradation. Oil contains a variety of types of hydrocarbons, and the natural microbe community may not have the capacity to deal with the type or size of hydrocarbons in a new spill. Scientists are considering seeding as an option for the Gulf if a large amount of oil remains on beaches, on rocks and in sediments along the coast.

The United States Environmental Protection Agency does not permit seeding with Genetically Engineered Microbes (GEMs) due to potential unintended effects of introducing new microbes into an ecosystem. For example, one unintended effect could be a Harmful Algal Bloom (HAB). In addition, currents and winds are unpredictable and may carry the new microbes beyond the target area into other ecosystems.

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## FOR FURTHER INFORMATION:

*What Happened To The Oil? Why Don't the Reports Agree?*

A frequently asked question and answer from The Science of the Spill: <http://www.spillscience.com/q.and.a.html>

*Meet the Microbes Eating the Gulf Oil Spill*

A slide show from Scientific American: [http://www.scientificamerican.com/slideshow.cfm?id=gulf-oil-eating-microbes-slide-show&photo\\_id=82271948-AD97-C1EC-F2F7027DBCD2BF5B](http://www.scientificamerican.com/slideshow.cfm?id=gulf-oil-eating-microbes-slide-show&photo_id=82271948-AD97-C1EC-F2F7027DBCD2BF5B)

*Deepwater Horizon Oil: Characteristics and Concerns*

The National Oceanic and Atmospheric Administration discusses the chemical nature of the Gulf oil, as well as weathering and cleanup methods: [http://sero.nmfs.noaa.gov/sf/deepwater\\_horizon/OilCharacteristics.pdf](http://sero.nmfs.noaa.gov/sf/deepwater_horizon/OilCharacteristics.pdf)



Special thanks to Dr. Jay Grimes of the Gulf Coast Research Laboratory (<http://www.usm.edu/gcrl/index.php>) at the University of Southern Mississippi for his contribution to this paper.

## SOURCES:

American Friends of Tel Aviv University, 2010. *Nemesis for oil spills: Bacterial technology may help clean up Gulf*. ScienceDaily. [http://www.sciencedaily.com/releases/2010/08/100803152817.htm?sms\\_ss=email](http://www.sciencedaily.com/releases/2010/08/100803152817.htm?sms_ss=email)

Biello, David. *Biological Breakdown. The job of cleaning up after the Gulf oil spill will fall to the microbes*. Scientific American; August 2010. <http://www.scientificamerican.com/article.cfm?id=biological-breakdown>

Biello, David. *How Long Will the Gulf of Mexico Oil Spill Last?* Scientific American; May 2010. [http://www.usnews.com/mobile/articles\\_mobile/scientists-say-gulf-spill-altering-food-web](http://www.usnews.com/mobile/articles_mobile/scientists-say-gulf-spill-altering-food-web)

Biello, David. *Slick Solution: How Microbes Will Clean Up the Deepwater Horizon Oil Spill*. Scientific American, May 25, 2010. <http://www.scientificamerican.com/article.cfm?id=how-microbes-clean-up-oil-spills>

Florida State University, 2010. *How fast can microbes break down oil washed onto Gulf beaches?* ScienceDaily. [http://www.sciencedaily.com/releases/2010/07/100707222312.htm?sms\\_ss=email](http://www.sciencedaily.com/releases/2010/07/100707222312.htm?sms_ss=email)

Hazen, Terry C., et al. *Deep-Sea Oil Plume Enriches Indigenous Oil-Degrading Bacteria*. Science 26 August 2010  
DOI: 10.1126/science.1195979. <http://www.sciencemag.org/cgi/content/full/science.1195979/DC1>

Leahy, Joseph G. and Rita R. Colwell. *Microbial Degradation of Hydrocarbons in the Environment*. Microbiological Reviews, September 1990, p. 305-315. Vol. 54, No. 3. <http://www.ncbi.nlm.nih.gov/pmc/articles/PMC372779/pdf/microrev00038-0103.pdf>

Microbe Zoo. Digital Learning Center for Microbial Ecology. <http://commtechlab.msu.edu/sites/dlc-me/zoo/index.html>

*Oil spills: microorganisms to the rescue?* Nature Reviews Microbiology 8, 462 (July 2010)  
<http://www.nature.com/nrmicro/journal/v8/n7/full/nrmicro2404.html>

Rapier, Robert. *Refining 101: The Assay Essay*. Consumer Energy Blog, January 2007. <http://www.consumerenergyreport.com/2007/01/11/refining-101-the-assay-essay/>

Temple University, 2010. *Low concentrations of oxygen and nutrients slowing biodegradation of Exxon Valdez oil*. ScienceDaily. <http://www.sciencedaily.com/releases/2010/01/100117150822.htm>

University of Illinois Extension, *Composting for the Homeowner. The Science of Composting*. <http://web.extension.illinois.edu/homecompost/science.html#1>