Oil Degradation in the Sea

David Coil, PhD, Director[1], Elizabeth Lester PhD[2], Bretwood "Hig" Higman, PhD, Executive Director[3]
contact@groundtruthtrekking.org

Last Modified: 5th November 2014

Summary

When oil enters the water from natural or manmade sources it begins to degrade, taking anywhere from days to decades depending on conditions. Processes that spread the oil through the environment usually speed up this degradation. However other factors such as colder water temperatures can inhibit these processes.

Where does the oil come from?

Oil enters the oceans from a large **variety of sources** , including oil spills, extraction of oil, operational discharge from ships, runoff from land-based sources, natural seeps, and volatile emissions. The amount of oil that enters the sea every year is difficult to measure; a 2002 estimate from the National Resource Council (NRC) put the possible range from **470,000 tons to 8.3 million tons** . The relative contribution of various sources is also hard to assess. For example, the 2002 NRC study estimated the percentage of oil from natural seeps at 47% of the total discharge, but **other studies** estimated 7% or 11%. It is generally accepted that land-based sources and operational discharges from ships and boats are generally responsible for far more oil in the ocean than the more famous tanker spills and well blowouts. However, spills and blowouts result in a high concentration of oil in one place, which has uniquely **negative consequences** such as the oiling of marine mammals and birds.

What happens to the oil in the water?

The fate of oil in the water depends on the type and amount of oil, temperature of the water, wind/wave/tidal action, types of microorganisms present, amount of oxygen, and a **large number of other factors** . As soon as oil enters the water it begins to break down through a **complex mix of processes** known as weathering: spreading, evaporation, dispersion, emulsification, dissolution, oxidation, sedimentation/sinking, and biodegradation.

Some oil is quickly degraded without doing any harm, but oil can remain in the environment unchanged for decades before having negative impacts. How much of the oil is degraded harmlessly depends on many factors, but generally degradation is accelerated by warm water, by mixing, and by the presence of microbes that can metabolize oil products. The ultimate products of all these processes are carbon dioxide and water but the degradation can take many years with numerous organisms being impacted along the way.

Spreading of oil over the surface of the water is a relatively rapid process. Within days, a single ton of oil could cover up to 12 square kilometers. The speed of spreading is affected primarily by the type of oil and the prevailing weather conditions. Spreading of oil can make cleanup more complicated but provides a larger surface area for weathering to occur.

Evaporation removes light petroleum products, such as kerosene and diesel, from the marine environment, but is much less relevant for heavy fuel oils and most crude oil. Spreading, higher temperatures, and rough weather all tend to increase the rate of evaporation.

Dispersion describes the breakup of oil on the surface of the water into drops or fragments that spread and sink into the water column. This is a critical step in the breakdown of oil in the sea, as it allows dissolution, biodegradation, and sedimentation to occur. **Chemical dispersants** are often applied to oil spills to increase the efficiency of this step. But dispersants are often themselves toxic, and the spread of oil below the surface increases its toxicity to fish and other subsurface organisms. The wisdom of speeding dispersion is hotly contested, as exemplified by the **ongoing debate** about the use of over 1.8 million gallons of

[1]David Coil, PhD, Director;
[2]Elizabeth Lester PhD;
[3]Bretwood "Hig" Higman, PhD, Executive Director; contact@groundtruthtrekking.org

dispersant during the **Deepwater Horizon spill** .

Emulsification refers to the process whereby two incompatible liquids become mixed. Milk, for example, is an emulsion of fat droplets of suspended in a solution of water, sugars, and proteins. In the case of spilled crude oil, sufficient turbulence can suspend droplets of seawater within the oil. The resulting emulsion is sometimes called "chocolate mousse". It significantly complicates cleanup of the oil, and decreases the efficiency of other processes such as dissolution and dispersion. Emulsification of oil in a marine environment is increased by wave or storm action at the surface and at lower temperatures.

Dissolution is what occurs when the soluble compounds of the oil are dissolved into the water. This is a relatively unimportant process since most of the soluble compounds in oil evaporate before they can dissolve.

Oxidation is a chemical reaction with the oil that can result in different outcomes depending on the type of oil and the availability of sunlight. The oil naturally reacts with oxygen, and generally forms more soluble and more toxic products. However oxidation reactions which are catalyzed by sunlight can lead to polymerization of oil molecules and lead to the formation of persistent "tar balls" which can last for a very long time without breaking down.

Sedimentation and Sinking of oil takes place slowly. Very few components of oil are dense enough to sink directly, but sedimentation can occur when the oil adheres to suspended particles or microbes in the water and then sinks.

Biodegradation of oil by microorganisms present in the sea is the often the slowest, but ultimately the most important, process in the natural degradation of oil. These organisms consume the oil, converting it to simpler and less harmful compounds in the process of metabolizing it to generate energy. The final byproducts of biodegradation are simply water and carbon dioxide, but some components of oil **last for years** before being degraded because for example they are not in demand, or the organisms that utilize them are low in number or normally live in distant habitats like deep sea seeps. The rate of biodegradation depends on the types of microorganisms present in the water, the availability of other nutrients, and the balance between the other weathering processes, described above, that affect the accessibility of oil for biodegradation.

"Bioremediation" refers to increasing the natural rate of biodegradation by supplying rate-limiting nutrients and oxygen to the affected area or seeding the area with the appropriate microorganisms. This technique has proven useful in lab settings and was used with some success on the shoreline after the **Exxon Valdez disaster**. However bioremediation has not been used on any large open water spills and **regulatory approval is still evolving** .

Persistence of oil in the environment

The persistence of petroleum products in the marine environment is extremely variable. On the one hand a cup of gasoline spilled from a filling station will most likely evaporate out of the environment in a matter of days. On the other hand, relatively unweathered crude oil can be **trapped for decades** on beaches, as happened in Prince William Sound after the **Exxon Valdez disaster**. Persistent patches of oil from the **1980 Ixtoc I well blowout** can also **still be found** on beaches in the Gulf of Mexico.

Date Created: 15th October 2010

Lingering Oil

Lingering 1989 Exxon Valdez oil in beach sediments on Smith Island in Prince William Sound, taken on August 26, 2010.

source: Copyright held by photographer