1 The Behavior and Effects Of Oil Spills In Aquatic Environments

INTRODUCTION

WHEN WE THINK of oil spills, we usually think of oil tankers spilling their cargo in oceans or seas. However, oil spilled on land often reaches lakes, rivers, and wetlands, where it can also cause damage. Oceans and other saltwater bodies are referred to as marine environments. Lakes, rivers, and other inland bodies of water are called freshwater environments. The term aquatic refers to both marine and freshwater environments.

When oil is spilled into an aquatic environment, it can harm organisms that live on or around the water surface and those that live under water. Spilled oil can also damage parts of the *food chain*, including human food resources.

The severity of the impact of an oil spill depends on a variety of factors, including characteristics of the oil itself. Natural conditions, such as water temperature and weather, also influence the behavior of oil in aquatic environments. Various types of habitats have differing sensitivities to oil spills as well.

PHYSICAL PROPERTIES OF OIL

THE TERM *OIL* describes a broad range of *hydrocarbon*-based substances. Hydrocarbons are chemical compounds composed of the elements hydrogen and carbon. This includes substances that are commonly thought of as oils, such as crude oil and refined petroleum products, but it also includes animal fats, vegetable oils, and other non-petroleum oils. Each type of oil has distinct physical and chemical properties. These properties affect the way oil will spread and break down, the hazard it may pose to aquatic and human life, and the likelihood that it will pose a threat to natural and man-made resources.

The rate at which an oil spill spreads will determine its effect on the environment. Most oils tend to spread horizontally into a smooth and slippery surface, called a *slick*, on top of the water. Factors which affect the ability of an oil spill to spread include *surface tension*, *specific gravity*, and *viscosity*.

- *Surface tension* is the measure of attraction between the surface molecules of a liquid. The higher the oil's surface tension, the more likely a spill will remain in place. If the surface tension of the oil is low, the oil will spread even without help from wind and water currents. Because increased temperatures can reduce a liquid's surface tension, oil is more likely to spread in warmer waters than in very cold waters.
- *Specific gravity* is the density of a substance compared to the density of water. Since most oils are lighter than water, they float on top of it. However, the specific gravity of an oil spill can increase if the lighter substances within the oil evaporate. Heavier oils, vegetable oils, and animal fats may sink and form *tar balls* or may interact with rocks or sediments on the bottom of the water body.
- *Viscosity* is the measure of a liquid's resistance to flow. The higher the viscosity of the oil, the greater the tendency for it to stay in one place. (Honey is an example of a highly *viscous* liquid.)

THE FATE OF SPILLED OIL

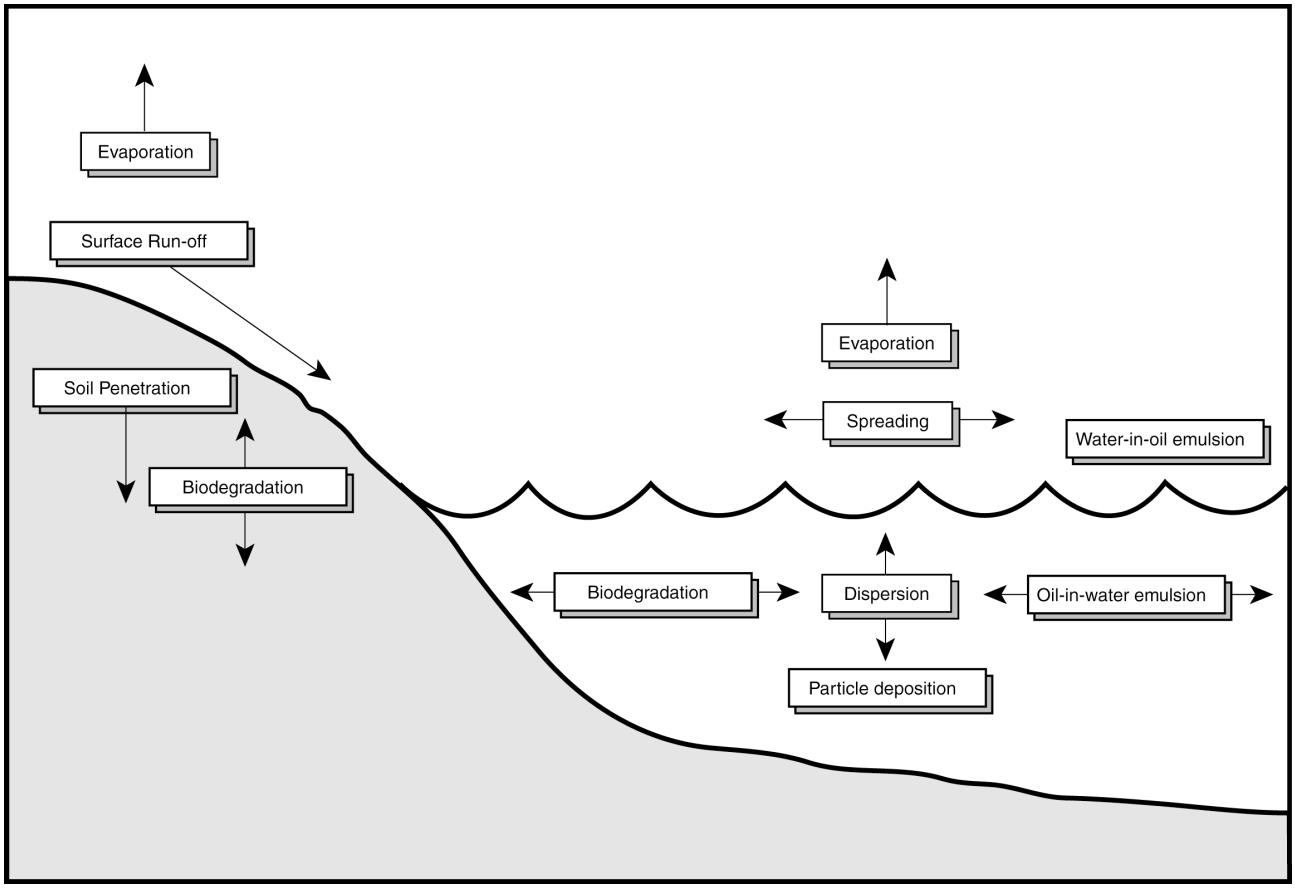
NATURAL ACTIONS are always at work in aquatic environments. These can reduce the severity of an oil spill and accelerate the recovery of an affected area. Some natural actions include *weathering*, *evaporation*, *oxidation*, *biodegradation*, and *emulsification*.

- *Weathering* is a series of chemical and physical changes that cause spilled oil to break down and become heavier than water. Wave action may result in natural *dispersion*,

breaking a slick into droplets which are then distributed vertically throughout the water column. These droplets can also form a secondary slick or thin film on the surface of the water.

- *Evaporation* occurs when the lighter or more volatile substances within the oil mixture become vapors and leave the surface of the water. This process leaves behind the heavier components of the oil, which may undergo further weathering or may sink to the bottom of the ocean floor. Spills of lighter refined products, such as kerosene and gasoline, contain a high proportion of flammable components known as light ends. These may evaporate within a few hours, causing minimal harm to the aquatic environment. Heavier oils, vegetable oils, and animal fats leave a thicker, more viscous residue. These types of oils are less likely to evaporate.
- *Oxidation* occurs when oil contacts the water and oxygen combines with the oil hydrocarbons to produce water-soluble compounds. This process affects oil slicks mostly around their edges. Thick slicks may only partially oxidize, forming *tar balls*. These dense, sticky black spheres may linger in the environment, washing up on shorelines long after a spill.
- *Biodegradation* occurs when microorganisms, such as bacteria, feed on oil hydrocarbons. A wide range of microorganisms is required for a significant reduction of the oil. To sustain biodegradation, nutrients such as nitrogen and phosphorus are sometimes added to the water to encourage the microorganisms to grow and reproduce. Biodegradation tends to work best in warm-water environments.
- *Emulsification* is the process that forms *emulsions*, which are mixtures of small droplets of oil and water. Emulsions are formed by wave action, and they greatly hamper weathering and cleanup processes. Two types of emulsions exist: water-in-oil and oil-in-water. Water-in-oil emulsions are frequently called "chocolate mousse," and they are formed when strong wave action causes water to become trapped inside viscous oil. Chocolate mousse emulsions may linger in the environment for months or even years. Oil and water emulsions cause oil to sink and disappear from the surface, giving the visual illusion that it is gone and the threat to the environment has ended.

These natural actions occur differently in freshwater versus marine environments. Freshwater environmental impacts can be more severe because water movement is minimized in these habitats. In standing water bodies, oil tends to pool and can remain in the environment for long periods of time. In flowing streams and rivers, oil tends to collect on plants and grasses growing on the banks. Oil can also interact with the sediment at the bottom of the freshwater bodies, affecting organisms that live in or feed off of sediments.



Fate of spilled oil.

EFFECTS OF OIL ON PLANTS AND ANIMALS

SOME TOXIC SUBSTANCES in an oil spill may evaporate quickly. Therefore, plant, animal, and human exposure to the most toxic substances are reduced with time, and are usually limited to the initial spill area. Although some organisms may be seriously injured or killed very soon after contact with the oil in a spill, non-lethal toxic effects can be more subtle and often longer lasting. For example, aquatic life on reefs and shorelines is at risk of being smothered by oil that washes ashore. It can also be poisoned slowly by long-term exposure to oil trapped in shallow water or on beaches.

Both petroleum and non-petroleum oil can affect the environment surrounding an oil spill. All types of oil share chemical and physical properties that produce similar effects on the environment. In some cases, non-petroleum oil spills can produce more harmful effects than petroleum oil spills.

Chapter five discusses in greater detail how oil spills impact wildlife .

Sensitivity of Aquatic Habitats

Aquatic environments are made up of complex interrelations between plant and animal species and their physical environment. Harm to the physical environment will often lead to harm for one or more species in a food chain, which may lead to damage for other species further up the chain. Where an organism spends most of its time—in open water, near coastal areas, or on the shoreline—will determine the effects an oil spill is likely to have on that organism.

In open water, fish and whales have the ability to swim away from a spill by going deeper in the water or further out to sea, reducing the likelihood that they will be harmed by even a major spill. Aquatic animals that generally live closer to shore, such as turtles, seals, and dolphins, risk contamination by oil that washes onto beaches or by consuming oil-contaminated prey. In shallow waters, oil may harm sea grasses and kelp beds, which are used for food, shelter, and nesting sites by many different species.

Spilled oil and cleanup operations can threaten different types of aquatic habitats, with different results.

- *Coral reefs* are important nurseries for shrimp, fish, and other animals as well as recreational attractions for divers. Coral reefs and the aquatic organisms that live within and around them are at risk from exposure to the toxic substances within oil as well as smothering.
- *Exposed sandy, gravel, or cobble beaches* are usually cleaned by manual techniques. Although oil can soak into sand and gravel, few organisms live full-time in this habitat, so the risk to animal life or the food chain is less than in other habitats, such as tidal flats.

Crews work to keep oil from entering a marsh.

- *Sheltered beaches* have very little wave action to encourage natural dispersion. If timely cleanup efforts are not begun, oil may remain stranded on these beaches for years.
- *Tidal flats* are broad, low-tide zones, usually containing rich plant, animal, and bird communities. Deposited oil may seep into the muddy bottoms of these flats, creating potentially harmful effects on the ecology of the area.
- *Salt marshes* are found in sheltered waters in cold and temperate areas. They host a variety of plant, bird, and mammal life. Marsh vegetation, especially root systems, is easily damaged by fresh light oils.
- *Mangrove forests* are located in tropical regions and are home to a diversity of plant and animal life. Mangrove trees have long roots, called *prop roots*, that stick out well above the water level and help to hold the mangrove tree in place. A coating of oil on these prop roots can be fatal to the mangrove tree, and because they grow so slowly, replacing a mangrove tree can take decades.
- *Marshes and swamps* with little water movement are likely to incur more severe impacts than flowing water. In calm water conditions, the affected habitat may take years to restore.
- *Other standing water bodies*, such as inland lakes and ponds, are home to a variety of birds, mammals, and fish. The human food chain can be affected by spills in these environments.
- *River habitats* may be less severely affected by spills than standing water bodies because of water movement. However, spills in these water bodies can affect plants, grasses, and mosses that grow in the environment. When rivers are used as drinking water sources, oil spills on rivers can pose direct threats to human health.

Sensitivity of Birds and Mammals

An oil spill can harm birds and mammals in several ways: *direct physical contact, toxic contamination, destruction of food sources and habitats*, and *reproductive problems*.

- *Physical contact* – When fur or feathers come into contact with oil, they get matted down. This matting causes fur and feathers to lose their insulating properties, placing animals at risk of freezing to death. For birds, the risk of drowning increases, as the complex structure of their feathers that allows them to float or to fly becomes damaged.
- *Toxic contamination* – Some species are susceptible to the toxic effects of inhaled oil vapors. Oil vapors can cause damage to the animal's central nervous system, liver, and lungs. Animals are also at risk from ingesting oil, which can reduce the animal's ability to eat or digest its food by damaging cells in the intestinal tract.
- *Destruction of food resources and habitats* – Even species which are not directly in contact with oil can be harmed by a spill. Predators that consume contaminated prey can be exposed to oil through ingestion. Because oil contamination gives fish and other animals unpleasant tastes and smells, predators will sometimes refuse to eat their prey and will begin to starve. Sometimes a local population of prey organisms is destroyed, leaving no food resources for predators. Depending on the environmental conditions, the spilled oil may linger in the environment for long periods of time, adding to the detrimental effects. In calm water conditions, oil that interacts with rocks or sediments can remain in the environment indefinitely.
- *Reproductive problems* – Oil can be transferred from birds' plumage to the eggs they are hatching. Oil can smother eggs by sealing pores in the eggs and preventing gas exchange. Scientists have also observed developmental effects in bird embryos that were exposed to oil. Also, the number of breeding animals and the of nesting habitats can be reduced by the spill. Long-term reproductive problems have also been shown in some studies in animals that have been exposed to oil.

SUMMARY

SPILLED OIL immediately begins to move and weather, breaking down and changing its physical and chemical properties. As these processes occur, the oil threatens surface resources and a wide range of subsurface aquatic organisms linked in a complex food chain. Many different types of aquatic habitats exist, with varied sensitivities to the harmful effects of oil contamination and different abilities to recuperate from oil spills. In some areas, habitats and populations can recover quickly. In other environments, however, recovery from persistent or stranded oil may take years. These detrimental effects are caused by both petroleum and non-petroleum oil.