Article Id
AL04462

OIL POLLUTION IN MARINE ENVIRONMENTS: A COMPREHENSIVE OVERVIEW

J. Bovas Joel

Email
jbovasjoelbfsc@gmail.com

TNJFU-Dr. M. G. R Fisheries College and Research Institute,
Thalainayeru- 614712, India

Oil pollution is one of the most visible and damaging threats to marine ecosystems. While the public generally associates oil spills with catastrophic tanker accidents or offshore drilling disasters, such as the 2010 Deepwater Horizon explosion in the Gulf of Mexico, the majority of oil pollution originates from less obvious, diffuse sources. Routine shipping operations, illegal discharges, and oil carried by rivers into the sea all contribute significantly to marine contamination. Alarmingly, these everyday sources account for about 90% of marine oil pollution, while large-scale disasters constitute only about 10%.Oil spills are regrettably common around the world: the Amoco Cadiz in France in 1978; the Exxon Valdez in Alaska in 1989; the 'Gulf War' in Kuwait in 1991; the Erica in France in 1999; the Aegean Sea in Galicia, Spain, in 1992; and the Prestige in Spain and France in 2002, which are some of the most well-known oil spills. Oil spills originate in oil platforms, refineries, or oil tankers that have an accident or that 'clean' their tanks in the ocean.

Globally, oil enters the marine environment through multiple pathways: 5% from natural seeps, 35% from shipping activities, 45% from atmospheric fallout and industrial discharge, and 5% from unidentified sources. The oil Itself, composed primarily of hydrocarbons, contains up to 10,000 different compounds, including toxic substances such as heavy metals and nitrogen compounds. Despite an increasing share of vegetable oils like palm oil in the global economy, fossil fuels remain the dominant pollutant.

Fate and Breakdown of Oil in Marine Waters

When oil is released into the ocean, it undergoes a series of physical, chemical, and biological transformations. Immediately, large slicks form and float on the surface. Volatile components evaporate, and the oil begins to spread, forming emulsions and dispersions in the water. Sunlight can cause photooxidation, altering the molecular structure of the oil, while some fractions dissolve in the water.

Over time, biological breakdown—primarily by bacteria—becomes the dominant degradation process. This rate depends on environmental factors such as temperature, wave action, oxygen levels, and nutrient availability. Warmer temperatures and higher oxygen and nutrient levels promote faster breakdown. The use of chemical dispersants can increase surface

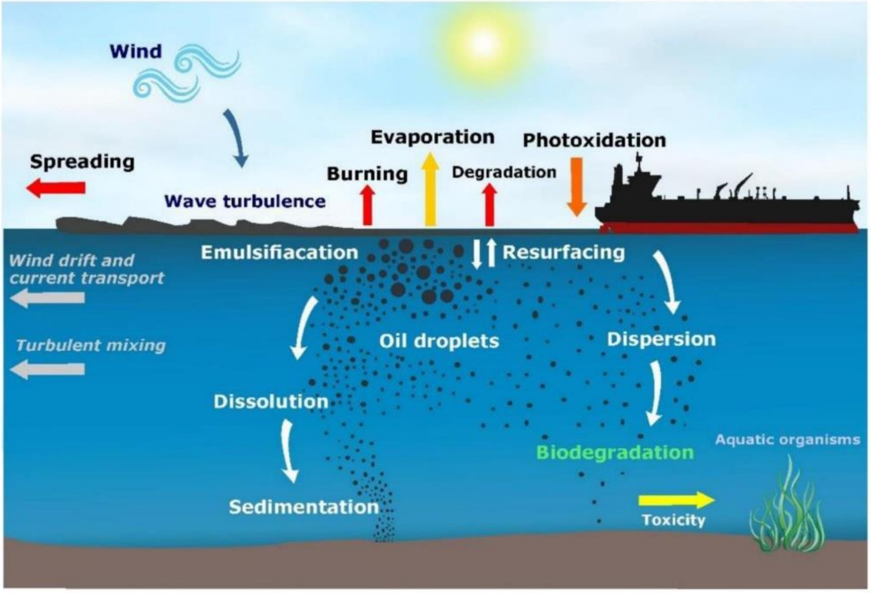

Fig 1: Transportation, weathering and fate of spilled oil in the marine environment. Adapted from Keramea et al.

area and speed up microbial degradation, although this approach comes with trade-offs, particularly in sensitive environments.

Some oil, especially heavier fractions, sinks or forms tarballs that are more resistant to breakdown. Emulsions like "chocolate mousse"—water-in-oil mixtures—can quadruple the volume of oil and severely hamper cleanup operations.

Impacts on Marine Habitats and Species

Oil spills affect marine habitats differently, depending on shoreline structure, exposure to wave action, and ecological sensitivity. Authorities use sensitivity rankings to prioritize clean-up efforts, often focusing on conservation areas and critical habitats.

- **Exposed Rocky and Sandy Shores** are considered low sensitivity areas due to natural cleansing by waves, but can still experience long-term shifts in species composition.
- **Sandy Beaches are more vulnerable**, especially those with coarse sediments and branching channels, which allow deeper oil penetration.

- **Coral Reefs are highly sensitive.** Oil can kill corals and disrupt complex symbiotic relationships, often resulting in long-term ecological shifts.
- **Mangroves, with their dense root systems and anoxic soils, suffer severely.** Oil kills flora and fauna, and hydrocarbon removal is extremely slow.
- **Soft Substrates and Sandbanks** such as those in the Wadden Sea host diverse benthic organisms. While bioturbation helps degrade oil, its absence due to mortality leads to prolonged contamination.
- **Salt Marshes** can suffer vegetation loss, which in turn affects breeding birds and other species. Recovery can take decades.
- **Regeneration periods vary widely**—from a few months for exposed shores to over 20 years for protected soft substrates and mangroves.

Response Mechanisms and Strategies

The effectiveness of oil spill response depends on rapid action, environmental conditions, and the scale of the spill. Mechanical containment methods include skimmers and floating booms, while chemical dispersants can be dropped from aircraft. However, dispersants are only effective in the early stages post-spill and may pose ecological risks of their own. In nutrient-poor waters, bioremediation—stimulating bacterial growth through nutrient addition—offers another option.

In the Deepwater Horizon disaster, oil was released at great depth, resulting in large underwater plumes. Dispersants were used extensively, raising concerns about long-term ecological effects. The need for well-coordinated national response plans has become evident. Countries like the US and Germany have established robust emergency frameworks, significantly improving response times and effectiveness.

Policy also plays a crucial role. The MARPOL 73/78 convention, the US Oil Pollution Act of 1990, and the ISM Code by the IMO have led to the mandatory use of double hull tankers and reduced operational discharges. These measures contributed to a significant drop in tanker-related pollution incidents since the 1980s.

Looking Ahead – Cautious Optimism and Continued Vigilance

Despite the increase in global oil transportation, marine oil pollution has declined significantly in recent decades. This positive trend results from international regulations, technological improvements, and stricter enforcement. However, major incidents like Deepwater Horizon are reminders that the threat remains.

Illegal discharges during tank-cleaning still contribute one-third of marine oil pollution. More rigorous monitoring and harsher penalties are required to address this ongoing issue. Shallow-water habitats, like the Wadden Sea, remain difficult to protect due to limitations in cleanup equipment.

The path forward requires integrated global and regional cooperation. Designating marine protected areas, enforcing international conventions, and developing new technologies for spill prevention and response are essential. Education and public awareness can also play a role in reducing pollution from land-based sources.

Conclusion

While significant progress has been made in reducing marine oil pollution, vigilance, innovation, and international collaboration remain key to protecting our oceans for future generations.

Reference

Keramea, P., Spanoudaki, K., Zodiatis, G., Gikas, G., & Sylaios, G. (2021). Oil spill modeling: A critical review on current trends, perspectives, and challenges. Journal of Marine Science and Engineering, 9(2), 181.

De la Huz, R., & López, J. (2011). Oil spills. In J. Nriagu (Ed.), Encyclopedia of Environmental Health (pp. 295–305). Elsevier.