NATIONAL ACADEMIES Sciences Engineering Medicine

Consensus Study Report
Highlights

Oil in the Sea IV
Inputs, Fates, and Effects

Oil and natural gas represent more than 50 percent of the worldwide energy supply, with high energy demand driven by population growth and improving standards of living. As the consumption, exploration, transportation, and production of oil has increased to meet demand, so have studies of the impacts of oil in the sea. Those studies have helped regulators implement new safety requirements, spill responders to develop innovative techniques, and industry to employ updated operational practices and safety measures to limit the impact of oil on the marine environment.

Despite significant progress in reducing the oil inputs to the sea, risks remain. The 2010 Deepwater Horizon (DWH) disaster resulted in the largest oil spill ever in North American waters. Alternative energy sources such as biofuels, ammonia, and hydrogen represent a growing share of the global energy mix, and in time may reduce the input of oil in the sea. However, oil will remain the major fuel source until other alternatives are available at sufficient scale and at a competitive cost.

With the support of many agencies and industry, the National Academies published reports in 1975, 1985, and 2003 on the sources, fates, and effects of oil in the sea. This report, the fourth in the series, documents the current state-of-knowledge on these topics, reflecting almost 20 years of additional research on long-term effects of oil spills on the environment from incidents including the Exxon Valdez oil spill and the DWH explosion and oil spill. The report identifies important gaps in research and understanding, taking account of the changing energy market.

SOURCES OF OIL IN THE SEA

The past 20 years have brought changes to the ways in which oil and natural gas are extracted, transported, and consumed—and potentially, can enter the sea (see Figure 1). The report's authoring committee made best estimates of the annual volume of oil entering the sea from different sources (focusing the analysis over the 10-year period from 2000 – 2019) and described the general trends:

1. Land-based sources by far outweigh other sources, even when including the DWH oil spill in the estimates. Comparing current estimates to those generated for the 2003 report (using the same methods and assumptions), land-based runoff has increased more than any other oil source, due to more densely populated coastal areas and the growing use of motor vehicles.

2. Natural seeps represent the second highest input.

3. Oil spills represent the third highest input, largely due to offshore spills in the Gulf of Mexico associated with oil and gas extraction. Over the past 20 years, and in particular since the DWH oil spill, improved safety regulations have significantly decreased the volume of spills from pipelines, tank vessels, non-tank vessels, and coastal refineries.

4. Operational discharges, including produced water (water discharged into the sea during oil and gas production) and discharges from machinery operations on commercial vessels, are the other major input. Increased offshore oil production has resulted in an increased estimated volume of associated oil pollution from produced water.

Chronic or continuous inputs have very different effects on marine life than accidental spills. The volume and rate of discharge and other factors, such as chemical composition, are important for determining the fate and effects of oil in the marine environment. A significant lack of systematic data collection concerning inputs of oil to the ocean, indicating little progress on recommendations related to quantifying oil inputs in previous reports. An independent group should report on the responsibilities of North American agencies to acquire more comprehensive data to better quantify oil inputs to the sea. The report recommends specific action be taken to better quantify inputs from seeps, land-based sources, atmospheric deposition, produced water, and marine vessel discharge compliance.

PREVENTION OF OIL IN SEA

Steps to prevent oil entering the sea through chronic land-based inputs include reducing gasoline vehicle usage, improvements in fuel efficiency and increased usage of electric vehicles, as well as improving car maintenance and the replacement of older vehicles. Many of these steps are being implemented in North America, and will likely continue in coming years. To prevent future accidents and oil spills, industry and federal and state agencies should:

- Continue best practices to prevent and reduce the magnitude of spills.

- Identify technical recommendations from investigations after the DWH oil spill that have not yet been implemented.

- Review capabilities of coastal onshore and offshore energy infrastructure to withstand increased frequency and intensity of extreme weather events.

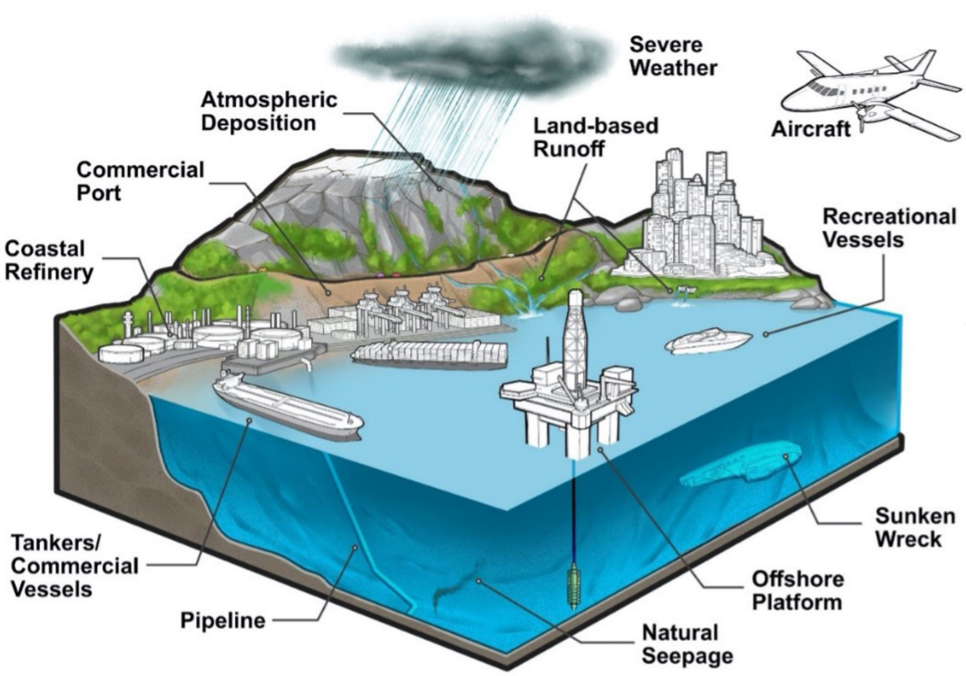

FIGURE 1 Sources of oil entering the marine environment. SOURCE: Courtesy of the American Petroleum Institute/Iron Octopus Productions, Inc.

- Take inventory of aging infrastructure, and prioritize salvage or capping of these facilities based on the potential impact if the infrastructure fails.

- Assess the economic and environmental impacts of changes in marine vessel transportation on pollution risk.

MINIMIZING THE EFFECTS

Although much is done to prevent and reduce amounts of oil entering the sea, accidental spills will continue as long as there is offshore production and transportation of oil. In the event of a spill, having tools available and plans in place will help minimize its effects. Considerations include:

- Regulatory mechanisms to encourage evaluation, permitting, and deployment of new response techniques when they become available.

- Enabling scientists to mobilize to the field quickly and work in concert with response operations.

- Prompt identification of vulnerable species such as seabirds, marine mammals, and shoreline biota and their ecological linkages to detect indirect effects on populations and ensure their protection.

SIGNIFICANT ADVANCES IN OIL SPILL SCIENCE

Over the past two decades, there has been unprecedented progress in oil spill science, made possible by 10 years of dedicated funding available after the DWH spill. Oil spill prevention and source control technologies have improved drastically. Advances in blowout prevention, use of the response toolbox concept, and development of risk assessment tools are a few examples of improvements leading to more effective, efficient, and holistic response operation.

The state of science of fates of oil in the ocean has also seen vast improvement in knowledge of physical, chemical, and biological processes and reactions that influence the fate of oil in the marine environment. Understanding the acute and chronic effects of oil pollution on marine and estuarine ecosystems is also an area of significant development, including new exposure scenarios, toxicity mechanisms of action, environmental modifiers of toxicity, effects on a greater range of habitats and species, long-term implications of oil spills, and effects of oil release on human health.

FIGURE 2 Booms contain oil in Adak Bay, Alaska, after a spill in January 2010. Source: NOAA

COMMON THEMES FOR ADVANCING OIL SPILL SCIENCE

To continue this progress and anticipate the challenges of a transitioning energy market, the report's authoring committee identified critical research needs among the interconnected topics of oil inputs, fates, effects, and response. A concerted and sustained effort in these key areas is needed to prepare for oil pollution challenges in the coming decades:

- Long-term funding: Oil spill science has been hindered by a boom-and-bust funding cycle and, consequently, the inability to sustain research and the scientific expertise. More sustained funding is needed to support multi-disciplinary research projects that address current knowledge gaps, address new regulatory requirements, and improve response capabilities.

- Human health: A healthy ecosystem includes the people working, living, and recreating along its shores and the sustainability of marine resources such as food, energy, and transportation. The governmental agencies involved in oil spill response should upgrade the priority and attention given to individual and community mental and behavioral effects and community socioeconomic disruptions in Incident Command System decision-making and response processes.

- Field experiments: Oil spill research generally takes place in a laboratory or test tank, which cannot simulate all the complexities and variability of field conditions. Controlled in situ field trials using real oils should be planned, permitted, and funded to incorporate multi-disciplinary research focused on important processes as well as response techniques that do not accurately scale from in vitro or ex situ experiments to in situ conditions.

- Arctic ecosystems: Marine traffic in Arctic waters is increasing with seasonal decreases in ice cover, and increased offshore Arctic oil production is a possibility. Field experiments in Norway, Canada, Alaska, Svalbard, and Greenland have uncovered complex processes affecting oil in Arctic environments, but utilizing this information in modeling or response requires additional work. A concerted effort to gather information about the fate of oil in Arctic marine ecosystems is needed.

- New fuels: New requirements for low sulfur fuel oils (LSFOs) for marine shipping came into effect in 2020, but studies on these oils are extremely limited. To understand the fate and effects of new marine fuels (including LFSOs and biofuels) so that response operations can be planned and executed most effectively to reduce their impacts, government should fund research on their composition, toxicity, and behavior in the sea.

- Baseline knowledge: A lack of pre-spill data on factors including physical oceanography, critical species, and biogeochemical processes makes it difficult to compare with post-spill observations and assessment of remediation. There is a need to review how pertinent knowledge and data from numerous sources are most effectively assembled, made available, and archived.

- Interdisciplinary research: Enormous streams of data have been generated from advances in analytical techniques, particularly in petroleum and environmental chemistry and in omics. A free, central, universally accessible and curated repository should be formed to better manage the data sets generated through advanced chemical analyses, omics techniques, geoscience surveys (among others), and especially field and laboratory studies pursuant to oil spills.

COMMITTEE ON OIL IN THE SEA IV: INPUTS, FATES, AND EFFECTS

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