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A Review of Oil Spills on Marine Life and Associated Wildlife

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A R T I C L E I N F O

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A B S T R A C T

Oil is an ancient fossil fuel used to power sectors like heat and electricity production. A wide range of fuels in automobiles and lubricants for mechanical machines have a significant role in our economy. Oil spills occur due to accidents, such as vessels crashing or being damaged, problems with oil platforms and drilling, and people making mistakes or equipment breaking down. Other causes include natural disasters like earthquakes, hurricanes, and volcanic activity underwater. Volcanic eruptions can release oil and gas stored beneath the seafloor. The intense heat and pressure can cause hydrocarbons to escape, forming oil slicks on the water's surface. We provide a summary literature review and overview framework to help communities systematically consider the factors and linkages that would influence the consequences of a potential oil spill. The focus is on spills from oil tanker accidents. Drawing primarily on empirical studies of previous oil spill disasters, we focused on several domains of interest: the oil spill, the physical marine environment, marine biology, human health, and policy.

Introduction

Oil spills are more common than you might think and happen in many ways. Crude oil spills are the most common and recognized type of oil spill. Crude oil, a naturally occurring fossil fuel extracted from beneath the Earth's surfaces, can be released into the environment through various means, such as offshore drilling accidents, pipeline rupture, or tanker collisions **[1-2].** The composition of crude oil is complex, containing a mixture of hydrocarbon, sulphur, nitrogen and trace elements. The consequences of the crude oil spill are severe, with immediate and long-term impacts on marine and terrestrial ecosystems.

Refined oil products, such as gasoline, diesel, or jet fuel, spill into the environment. These spills often result from transportation accidents, industrial mishaps or leaks from storage facilities. Unlike crude oil spills, refined oil product spills are characterized by higher volatility and the presence of additional chemicals used in the refining process. The heavy fuel oil is thick and dense and is used in shipping and industrial processes. These spills often occur during maritime accidents **[3],** where vessels carrying heavy fuel oil may run aground, collide, or experience technical failure. One notable heavy oil spill occurred after the MV Wakashio grounding in Mauritius in 2020. The spill had severe ecological consequences, impacting coral reefs, mangrove forests, and marine life. The slow weathering of heavy fuel oil in tropical environments exacerbates the persistence of its impact, highlighting the unique challenges associated with this type of oil spill.

Pipeline Leaks and Spills

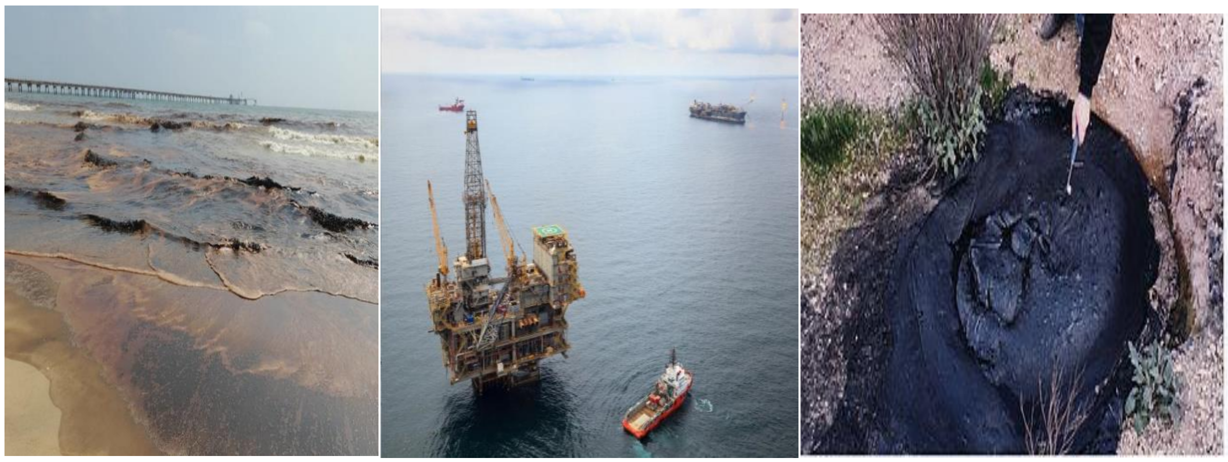
Pipeline leaks and spills are another category of oil spills, often due to corroded pipelines, equipment failures, or external damage. Oil transportation through pipelines is a critical component of the energy infrastructure but comes with inherent risk. The extent of damage from a pipeline spill depends on factors such as the volume and type of oil released, the speed of response efforts, and proximity to sensitive ecosystems **[4].**

Offshore Drilling Accidents

Offshore drilling introduces the risk of oil spills through well blowouts, **[5-7]** platform accidents, or equipment failures. The Deepwater Horizon oil spill in 2010, one of the most infamous offshore drilling accidents, resulted in the release of millions of barrels of crude oil into the Gulf of Mexico; the largest spill in the United States was the Exxon Valdez **[8-9]** spill into Prince William Sound, Alaska, in March 1989.

Natural seepage

While human activities significantly contribute to oil spills, natural seepage from the Earth's crust also releases oil into the environment **[10].** Oil seepage occurs through fissures in the ocean floor terrestrial surfaces, which has been happening for millions of years. Natural seepage contributes to the presence of oil in marine environments, creating ecosystems that have adapted to the continuous input of hydrocarbons.



(a) (b) (c)

Figure 1: (a) Pipeline leak of a spill (b) Drilling accident (c) Natural seepage of oil

Crude oils are complicated combinations of hydrocarbons, Such as alkane, cycloalkane, benzene, ethylbenzene, and polycyclic aromatic hydrocarbon, but with some nitrogen, sulphur and oxygen. Most of the toxicity found in oil is caused by aromatic hydrocarbons, which include one or more benzene rings. At low ambient temperatures, the hydrocarbons with the lowest molecular weights are typically volatile and have the lowest boiling points. They evaporate quickly, and their effect on marine life is typically low. If released in deep water, low molecular hydrocarbon causes greater toxicity but generally biodegrades rapidly. High molecular weight hydrocarbons (asphaltenes) have a high boiling point and are opposed to biodegradation. They may also be chronically toxic, which has the potential to cause biological impacts.

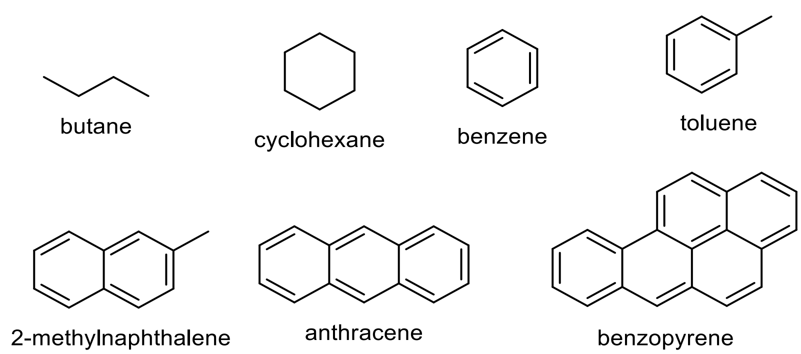


Figure 2. Examples of the chemical compounds' structures found in crude oils

Biodegradation

In order to use hydrocarbons from crude oil as a food source, marine bacteria have evolved to manufacture enzymes **[11].** Hydrocarbons undergo growth and reproduction through metabolism, serving as a source of sustenance for various organisms in a natural cycle. This process facilitates the biodegradation of the majority of spilled oil, with its energy and materials reintegrated into the food chain. Effective degradation relies on sufficient oxygen, nutrients, and trace elements, and the speed is influenced by the oil's surface area-to-volume ratio – finely dispersed droplets degrade quickly, while thick slicks or shoreline patches degrade more slowly. Large hydrocarbon molecules, particularly some potentially harmful PAHs, resist rapid biodegradation and can persist for extended periods.

Effects of oil spills on wildlife that is related to marine life

Microbes (bacteria, etc.), phytoplankton (small, frequently single-celled algae), and zooplankton (mostly small crustacea, **[12-16]** but also jellyfish and other animals) are all considered to be forms of plankton, along with the spores, eggs, and larvae of other plants and animals (fish, algae, and invertebrates). Plankton densities are highest in coastal waters where nutrient concentrations are near adult populations and high enough to support them. The majority of marine food networks are based on this substantial diffuse biomass. Planktonic organisms are highly susceptible to the harmful effects of hydrocarbon exposure, especially from water-soluble fractions and minute oil droplets. Extensive research conducted in lab settings has documented a broad spectrum of acute, long-term, and non-lethal consequences on different species and phases of life. However, once the oil-in-water concentrations have reverted to background levels, the majority of research on natural plankton populations in the sea have demonstrated a swift return to normal densities and community composition. The rapid recovery capability of certain species is attributed to their short generation times, prolific egg and juvenile production, widespread distribution, and swift water exchange. Limited studies have documented planktonic species' density effects lasting beyond a few weeks. For instance, research following the 1977 grounding of the Soviet tanker Tsesis, releasing 1,000 tonnes of medium-grade fuel oil into the Baltic Sea, revealed a substantial decline in zooplankton biomass near the wreck in the initial days post-spill, but recovery occurred within five days. In the event of a sizable spill in the same area during spawning or post-spawning phases, there could be notable mortality among eggs or larvae. Despite the substantial number of eggs produced by most fish and the minor proportion needed for adult stock maintenance, the likelihood of a spill having a detectable impact on the fish population remains low. The western Atlantic bluefin tuna in the Gulf of Mexico is one recent example of this worry; these fish are known to breed in an area that largely coincides with the sea area impacted by the 2010 Macondo well blowout oil leak and lay surface-floating eggs. Hydrocarbons may have an impact on the development of Southern bluefin tuna embryos, according to Australian studies, suggesting a potential mechanism for effects. Nevertheless, there is no indication of any consequences from field research on Atlantic Bluefin tuna in the Gulf of Mexico, according to published results.

Seabed life

The bulk of seabed habitats in offshore regions are made up of sediments, which are diverse combinations of mud, sand, and gravel **[17-18].** Certain species or groups of species, such as those found in kelp forests, seagrass beds, mussel beds, and coral reefs, dominate or even establish habitats. Seagrass beds and algae can only be found in light-filled, rather shallow water, up to a few tens of meters. Nevertheless, animal populations exist at all depths. Since ecologically significant amounts of dissolved or dispersed oil from surface slicks seldom fall below 10 meters, seabed ecosystems' susceptibility to oil from surface spills is mostly dependent on water depth. Moreover, it is rare for elevated concentrations to persist across a specific area of the ocean floor for an extended period. The possibility that concentrations of hydrocarbons with potentially harmful effects may reach even shallow seabed locations diminishes as slick weather and goes on. Any organisms directly exposed to the water column, such as the epibiota—a group of plants and animals that live on the seabed's surface—and any burrowing animals that actively draw water into their burrows or tissues for irrigation or feeding, will be at risk in the unlikely event that elevated concentrations of oil in water do reach the seabed.

Shallow water seabed epibiota may exhibit susceptibility to oil concentrations in close proximity to the bottom; however, many species tend to be relatively resilient even in the presence of elevated concentrations, as the typical duration of exposure is short. The impact of oil on macroalgae, including kelp and various other species prevalent on hard substrata in shallow waters, is minimal due to their mucilaginous coating, which acts as a barrier against oil absorption. Certain sessile invertebrates, including those that engage in filtering or particle capture from the water column and thus readily uptake oil droplets, such as sponges and sea squirts, often demonstrate survival with apparent immunity to high concentrations. The deep sea harbors a rich diversity of marine life, and its vulnerability to surface spills is limited; however, there exists potential for hydrocarbon exposure resulting from subsurface spills. Animals in this environment may experience temporary effects from a brief, intense dose of hydrocarbons, but fatalities are not observed. Mussels provide an illustrative example: while they readily accumulate oil from the water column in their tissues, they demonstrate resistance to its toxic effects.

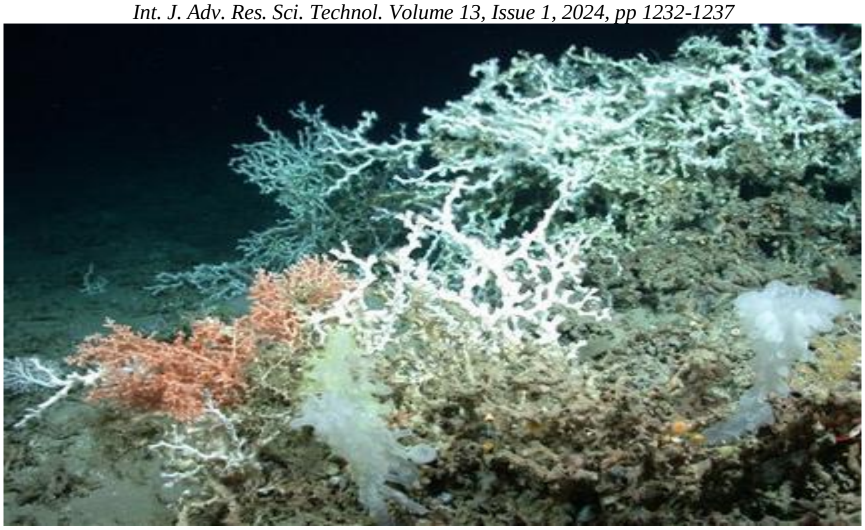


Figure 3: Oil spill hurt seabed life

Marine reptiles

Turtles face potential vulnerability to oil exposure when they encounter it either on the sea's surface or along the shore. Although adults and juveniles spend limited time at the surface outside the nesting season, their need to periodically breathe air makes them susceptible to oil contact during those intervals. While there is a risk of oiling during such surface periods, there is little evidence suggesting sensitivity of their skin. Given that turtles are widely distributed and do not aggregate, it is improbable that impacts would lead to population-level effects. However, heightened risk occurs during the nesting season when adult females come ashore, typically at night, and crawl to the top of a sand beach to lay their eggs. This activity is strongly seasonal, potentially involving a significant number of females returning to the same beach simultaneously. The nests, being deeply buried in the sand, offer substantial protection to the eggs, making them largely resistant to contamination unless exposed to significant fresh light oiling. However, the vulnerability of hatchlings increases, particularly during their synchronized hatching and movement across the shore to minimize predation losses. This synchronization, while beneficial for predation avoidance, renders them more susceptible to oil contamination if a spill coincides with this event. Unlike adults, juveniles are more sensitive to oil toxicity, spend more time at the sea's surface, and may ingest small tar balls. Instances of juvenile turtle deaths have been reported following some oil spills, with autopsies revealing the presence of oil and tar balls in their intestines. While the theoretical possibility of severe impacts on a turtle nesting site during the nesting season exists, no such effects have been reported thus far **[19].** Other reptiles, such as marine iguanas, crocodiles, alligators, and sea snakes, inhabit the sea's surface, shallow waters, and shorelines. While there are potential routes for oil exposure, further research is needed due to limited studies on the effects of oil on these species.

Figure 4: Body of an oil-covered turtle death

Seabirds

There are three ways that oil can affect birds: by physically oiling their feathers, which can lead to hypothermia and a decreased capacity to move, feed, etc.; by ingesting oil while preening or eating contaminated food; and by transferring oil to eggs and young, which may lead to a decreased chance of survival. The lasting effects of multiple oil spills have left behind heartbreaking pictures of dead and crippled seabirds with oil all over their feathers. The confirmed toll of avian casualties has occasionally topped several thousand. Species and life stages have a major impact on how sensitive and vulnerable birds and bird populations are to oil spills; the amount of time birds spend on the water's surface also plays a major role in this regard. Many shorebirds including oystercatchers, curlews, and plover, as well as many seabirds like terns, gannets, and shearwaters, seldom or never sit on the water. In comparison to the native populations, those species usually have a low number of oil spill casualties. However, because they live their whole lives on the water, sea ducks, grebes, and auks (members of the Alcidae family, which includes guillemots and razorbills) are far more likely to get oil if a surface slick occurs in the area where they are present. A few notable instances are the gatherings of auks near breeding colonies, especially early in the spring when the adult birds have not yet returned to their nests and close to the end of the breeding season when the flightless young and moulting adults are getting ready to migrate offshore. Before beginning their long-distance migrations between high-latitude summer breeding sites, milder winter sites, and specific refueling stops en route, some sea ducks and grebes congregate.

Figure 5: Death of seabirds at oil spill

Effect on human health

Oil spill-cleanup workers, for instance, suffer from damaged immune, respiratory and cardiac functions and carry high levels of toxicity that have long-term consequences. The oil includes high levels of toxic chemicals, which can harm humans who come into contact with or ingest the oil. Direct exposure to crude oil and its components can irritate the respiratory system, leading to symptoms like coughing, shortness of breath, and exacerbating pre-existing respiratory conditions. Skin contact with oil can cause irritation, rash, and dermatitis, while exposure to the eye may result in irritation and discomfort. Indirectly, the contamination of water sources due to oil spills can affect human health by consuming contaminated seafood. Fish and shellfish accumulate harmful substances from oil, like polycyclic aromatic hydrocarbons (PAHs), which are known as carcinogenic and cause various types of cancer in humans.

Oil Spill Prevention

Oil spills can have devastating environmental and economic impacts, making prevention crucial. However, effective methods are used to control the oil spills. Regular equipment maintenance of oil extraction, storage, and transportation equipment minimizes the risk of leaks and malfunctions. Regular inspections and timely repairs are essential. Ensure that any damaged items are replaced. Make sure there is an oil safety valve on your heating system. It's time to install one if you don't already have one. If the line breaks, this instantly cuts off the oil supply. Safety protocols implementing strict safety procedures during oil transfer operations, such as loading and unloading, help prevent oil spills. Underwater leak detection systems use real-time sensors to identify pipeline and subsea infrastructure leaks.

Indian Coast Guard (I.C.G.) is the Central Coordinating Authority in India for matters related to Oil Spills. The National Oil Spill Disaster Contingency Plan (NOSDCP) promulgated by the I.C.G. is the apex plan for responding to oil spill disasters in Indian waters. It applies to shipping, ports, and oil industries.

Conclusion

Marine oil spills can have a serious impact on marine life. Generally, the effects of the oil toxicity depend on the characteristic physical and chemical condition exposure routes and regimen and bioavailability of the oil. Oil dispersants, a standard tool used after oil spills, are also toxic and threaten pelagic and benthic organisms and fish. Cleanup efforts and physical harm to the environments that support plants and animals can also have an indirect impact on marine life. Communities threatened by marine oil spills have realized the risk and have, therefore, developed their own plan and policy issues to counteract the risk of oil spill contamination.

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Useful websites:

Deepwater Horizon, Bibliography of Published Research: www.lib.noaa.gov/researchtools/subjectguides/dwh.html

Exxon Valdez Oil Spill Trustee Council: www.evostc.state.ak.us

Interspill: www.interspill.org/previous-events

IOSC: www.ioscproceedings.org/loi/iosc

TOPF: www.itopf.com/knowledge-resource

NOAA: http://response.restoration.noaa.gov/publications

PREMIAM: www.cefas.defra.gov.uk/premiam/publications.aspx

www.fairplanet.org/story/ocean-oil-spills-and-its-impact/