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"OPERATIONAL POLLUTION FROM SHIPS: LEGAL INSTRUMENTS AND ENFORCEMENT MECHANISMS"

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ABSTRACT

Operational pollution from ships, which results from everyday maritime activities such as emissions, ballast water discharge, sewage, waste disposal, and fuel use, endangers marine ecosystems, coastal populations, and global climate goals. Operational discharges, unlike unintentional contamination, occur over time and are frequently invisible to authorities. This paper critically explores the international legal system governing such pollution, with an emphasis on treaties like as MARPOL, UNCLOS, the Ballast Water Management Convention, and related liability regimes. It also looks at regional and national legal responses, as well as the changing regulatory landscape in India. The study delves into various enforcement strategies, including flag state control, port state inspections, coastal state authority, and developing monitoring and detection technology. Empirical evidence from IMO audits, satellite monitoring, and real-world enforcement operations reveals significant gaps in compliance and capacity, especially in developing countries. The paper identifies systemic challenges including weak flag state oversight, under-resourced port authorities, limited detection infrastructure, jurisdictional ambiguity, and insufficient penalties. Ultimately, it argues for a more integrated and accountable regime to reduce ship-sourced operational pollution and safeguard the marine environment.

KEYWORDS- *Operational pollution, international conventions, Flag state, Port state, IMO audits*

1. INTRODUCTION:

The 20th century has arguably been the oil century. As every country dependent on this black gold for industrialisation and transportation. oil consumption, exploration and importation have been on a rise. since global trade relies heavily on maritime transportation, the increasing number of vessels navigating through our seas has resulted in various forms of pollution, including oil spills[1609].

Oil spills are environmental disasters caused by the release of petroleum or its derivatives into the ocean or coastal waterways, which is frequently the result of tanker, drilling rig, or pipeline accidents.[1610] These catastrophes can have devastating consequences for marine ecosystems, with immediate effects including water contamination and habitat destruction, as well as long-term effects such as chronic health difficulties for marine animals and disruption of food chains. These spills can occur at any point of the oil transportation process, including loading, unloading, and transit, and are usually caused by human mistake, equipment failure, or adverse weather conditions. The release of crude oil or refined products into the ocean can cause significant

[1609] International Convention for the Prevention of Pollution from Ships (MARPOL), https://www.imo.org/en/about/conventions/pages/international-convention-for-the-prevention-of-pollution-from-ships-(marpol).aspx (last visited Sep. 10, 2025).

[1610] Oil Spills | National Oceanic and Atmospheric Administration, https://www.noaa.gov/education/resource-collections/ocean-coasts/oil-spills (last visited Sep. 11, 2025).

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environmental damage, hurting marine life, habitats, and the lives of those who rely on coastal resources.

Historically, shipping, like many other commercial activities, evolved in ways that neglected environmental consequences and effectively passed on the expense of coping with them to coastal states and innocent third parties. Only in 1967, when the tanker Torrey Canyon ran aground on the coast of Cornwall, were the flaws in environmental protection, as well as the weaknesses of national and international legal frameworks for dealing with such large-scale pollution, were exposed.[1611]

2. OPERATIONAL POLLUTION

Operational pollution refers to a variety of pollutants discharged or emitted during the routine operation of ships. It varies from unintentional pollution in that it is ordinary and continual, rather than sudden or catastrophic. The most prevalent sources of operational pollution include oily water discharges from engine rooms, sewage from toilets and showers, food waste and plastics in general rubbish, ballast water containing invasive species, and exhaust emissions from heavy fuel oil combustion.[1612] Each form of pollution has a unique impact on the environment and necessitates different technical and legal mitigation strategies.

Oil pollution, while historically linked with big tanker accidents, remains a serious problem due to operating releases. Under normal conditions, ships produce oily bilge water, which must be treated before being released at sea. Similarly, inappropriate sewage and garbage disposal, particularly of plastics, contributes to marine contamination. Ballast water creates ecological concerns by introducing non-native species into local ecosystems, altering biodiversity and hurting fisheries. Ship emissions are also causing concern since they contribute to climate change and local air pollution. The regulation of operational pollution necessitates a comprehensive and integrated legislative framework that tackles each pollutant source efficiently.

3. EARLY INCIDENTS OF OIL SPILLS

The 20th century saw a rapid expansion of the oil industry, particularly with the introduction of offshore drilling, the increased use of oil tankers for transportation, and petroleum's emergence as a major worldwide energy source.[1613] This expansion led to a rise in the number and size of oil spills, many of which had severe environmental implications.

The 1940s-1950s: Oil spills were more common during and after World War II as the number of ships, submarines, and aircraft powered by petroleum rose. Some of these disasters were caused by military activity, such as the deliberate spilling of oil into the water. However, the true expansion of oil spills caused by industrial practices began in the postwar years, as oil demand increased quickly.

The 1960s: The decade saw some of the first large oil spills linked to offshore drilling. One of the most noteworthy early accidents occurred in 1967, when the Torrey Canyon, a super tanker carrying 120,000 tons of crude oil, ran aground off the coast of Cornwall in England. The leak dumped millions of gallons of crude oil into the English Channel, inflicting widespread environmental harm. This occurrence was a watershed moment in the history of oil spills, demonstrating the perils of shipping oil by sea.

The Exxon Valdez Spill and the 1980s: One of the most memorable and consequential oil spills in modern history occurred in 1989, when the oil ship Exxon Valdez collided with a reef off the coast of Alaska. The leak dumped over 11 million gallons of crude oil into Prince William

[1611] Remembering the Torrey Canyon Oil Spill | OSRL News, Osrl, http://www.osrl.com/media/news/remembering-the-torrey-canyon/ (last visited Sep. 12, 2025).

[1612] Environment and Pollution - MARPOL, North Standard | Marine Insurance, http://north-standard.com/insights-and-resources/resources/archive/articles/environment-and-pollution-marpol-2791 (last visited Sep. 13, 2025).

[1613] Read "Oil in the Sea III: Inputs, Fates, and Effects" at NAP.Edu, https://nap.nationalacademies.org/read/10388/chapter/2 (last visited Sep. 14, 2025).

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Sound, damaging nearly 1,300 miles of shoreline. The Exxon Valdez spill decimated nearby wildlife populations, including sea otters, seabirds, and fish species. The leak also caused widespread disruptions in the region's fishing and tourism businesses.

This incident was critical in raising public awareness about the dangers of oil spills and exposing the vulnerabilities of distant coastal habitats. It spurred the U.S. government to pass the Oil Pollution Act of 1990, which significantly improved spill response mechanisms and created more stringent regulations for the oil industry.[1614]

The 1990s and Early 2000s: Further Spills and Growing Regulation: Following the Exxon Valdez spill, numerous other significant oil spills occurred, each with varied degrees of environmental and economic impact.

The 1991 Gulf War Oil Spill: As Iraqi forces were retreating, an estimated 11 million barrels of oil were deliberately spilled into the Persian Gulf. The oil leak, one of the greatest in history, covered thousands of square kilometres and caused substantial harm to marine life and the regional fishing sector. The Gulf War oil spill demonstrated the use of oil as a weapon of war, emphasizing the importance of international collaboration in preventing and responding to oil disasters.[1615]

The 2000s: The early 2000s brought new issues in oil spill management, notably with offshore drilling. In 2004, the Castillo de Bellver incident occurred when an oil tanker collided with another ship off the coast of Spain, spilling approximately 12 million gallons of crude oil into the Mediterranean Sea. However, the 2010 Deepwater Horizon spill had the most long-term impact on oil spill legislation and response.

The Deepwater Horizon Disaster: In 2010, the Deepwater Horizon drilling rig, operated by BP, suffered a catastrophic explosion in the Gulf of Mexico, leading to one of the most devastating oil spills in history. The explosion killed 11 workers and caused an estimated 4.9 million barrels of crude oil to leak into the ocean over the course of 87 days. The spill wreaked havoc on thousands of miles of coastline, decimated marine and wildlife populations, and caused major economic harm to the regional fishing and tourism businesses.

The Deepwater Horizon disaster exposed major flaws in the oil industry's safety protocols and its ability to respond to spills in deepwater environments. The environmental impact was profound, with entire ecosystems being affected by the massive oil release. Efforts to stop the spill, such as capping the well and using subsea robots, were not successful until months after the initial blowout, highlighting the limitations of technology in dealing with such large-scale disasters. In the aftermath of the spill, BP faced billions of dollars in fines, penalties, and compensation claims. The U.S. government, led by the Obama administration, imposed tighter regulations on offshore drilling, including requiring companies to submit more robust safety plans and technologies for deepwater drilling.[1616]

The 21st Century: A New Focus on Prevention and Innovation: Despite the industry's advancements in prevention and mitigation, oil leaks remained a significant concern after the Deepwater Horizon disaster. Globally, safety regulations have been reinforced and offshore drilling technology has advanced, especially in offshore oil exploration.

4. Legal Instruments Governing Operational Pollution

4.1 Global Conventions and Treaties

The backbone of international regulation of operational pollution from maritime sources

[1614] Details about the Accident, Exxon Valdez Oil Spill Trustee Council, https://evostc.state.ak.us/oil-spill-facts/details-about-the-accident/ (last visited Sep. 6, 2025).

[1615] AESG, Oil Spills in the Arabian Gulf: A Case Study and Environmental Review - Engineering Consultant | Specialist Consultancy, https://aesg.com/perspective/oil-spills-in-the-arabian-gulf-a-case-study-and-environmental-review/ (last visited Oct. 6, 2025).

[1616] Deepwater Horizon Oil Spill | Smithsonian Ocean, https://ocean.si.edu/conservation/pollution/gulf-oil-spill (last visited Sep. 30, 2025).

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is the MARPOL Convention (International Convention for the Prevention of Pollution from Ships, 1973, as amended by the 1978 Protocol). MARPOL contains multiple annexes dealing with different pollution types: Annex I (oil), Annex II (noxious liquid substances in bulk), Annex III (harmful substances in packaged forms), Annex IV (sewage), Annex V (garbage), and Annex VI (air pollution, including sulphur oxides, nitrogen oxides, ozone-depleting substances, and more recently greenhouse gas-related measures).[1617] These annexes set out prohibitions, discharge criteria, emission limits, shipboard record keeping, and certification requirements.

The United Nations Convention on the Law of the Sea (UNCLOS), which lays out general obligations for governments (flag states, coastal states) regarding pollution from vessels, is another important tool. For instance, states are required by Part XII of UNCLOS to enact laws and regulations to prevent, lessen, and regulate pollution of the maritime environment; to guarantee that boats operating under their flag or under their authority adhere to international norms and standards; and to collaborate on pollution-related matters. The legal foundation for jurisdictional claims, coastal state accountability, and the need for flag state supervision is provided by UNCLOS.

Other important treaties include the Ballast Water Management Convention (BWM) which addresses the problem of invasive species carried in ballast water; the Anti-Fouling Systems Convention for regulating harmful anti-fouling paints; and liability/compensation conventions such as the International Convention on Civil Liability for Oil Pollution Damage (CLC), the Bunker Oil Pollution Damage Convention (BUNKER), and the Hazardous and Noxious Substances (HNS) Convention.

4.2 Regional and National Instruments

Various maritime regions have regional agreements or directives that implement or supplement international treaties. For instance, the European Union has laws on ship-generated waste port reception facilities, more stringent emission control in Emission Control Areas (ECAs), and rules for reporting and monitoring.[1618] States are also required under regional seas programs, such the Mediterranean Barcelona Convention, to reduce pollution.

National laws enforce international commitments domestically, adapt them according to local socioeconomic, geographic, and environmental circumstances, and frequently introduce new requirements. For instance, many nations have laws that specifically address environmental protection, air pollution, port and navigation regulations, and the avoidance of marine pollution (such as the Merchant Shipping Acts). For example, sewage discharge requirements are enforced in India by regulations like the Merchant Shipping (Prevention of Pollution by Sewage from Ships) Rules, 2010. Until more precise shipping regulations are revised, Indian courts (and tribunals) have ruled that foreign-flagged vessels entering Indian Maritime Zones are subject to environmental legislation including the Environment (Protection) Act, 1986, and the Air (Prevention and Control of Pollution) Act, 1981.

Also, recent proposed and enacted legislation (Merchant Shipping Bill, Indian Ports Act) seeks to modernize alignment with international standards.

4.3 Enforcement Mechanisms

4.3.1 Flag State Enforcement

Under international law, the flag state (i.e., the state under whose flag a ship is registered) has primary responsibility for

[1617] Raunek, MARPOL (The International Convention for Prevention of Marine Pollution for Ships): The Ultimate Guide, Marine Insight (Mar. 4, 2024), https://www.marineinsight.com/maritime-law/marpol-convention-shipping/.

[1618] ECA (Emission Control Area), Sustainable Ships, https://www.sustainable-ships.org/rules-regulations/eca (last visited Oct. 6, 2025).

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ensuring its vessels comply with international conventions. Enforcing shipboard operational standards, conducting surveys and inspections, providing certificates (such as MARPOL certificates), and penalizing non-compliance are all part of this. Flag states are required to make sure their ships have the necessary equipment (such as exhaust scrubbers and oil water separators), adhere to discharge guidelines, keep logs, and manage emissions.[1619]

However, in reality, flag state enforcement frequently encounters significant obstacles. Some flag states have been described as "flags of convenience," which means that they have inadequate regulatory control, limited enforcement capabilities, or perhaps insufficient funding or political will to conduct routine vessel inspections.

4.3.2 Port State Control

Another important enforcement tool is provided by Port State Control (PSC). When foreign vessels call in a coastal or port state, PSC permits inspections to ensure adherence to international agreements (MARPOL, SOLAS, etc.). Port states have the authority to hold ships, deny entrance or exit, demand corrective action, or impose fines if flaws are discovered (such as incorrect discharge, missing documents, or emission non-compliance).

PSC agreements are frequently arranged on a regional basis. Memoranda of Understanding (MoUs), like the Paris and Tokyo MoUs, among others, establish guidelines and offer structures for member governments to work together on PSC.[1620] PSC works best in areas with robust legislative frameworks, strong regulatory capacity, and political will; it is less successful in areas with remote ports, expensive inspections, or lax enforcement.

4.3.3 Coastal State Jurisdiction

According to national law and UNCLOS, coastal nations have jurisdiction over pollution in their territorial seas and are subject to specific duties within their Exclusive Economic Zones (EEZs). They can establish environmental regulations that apply within their jurisdictions and control emissions, discharges, and other ship operations, including ship routing. Therefore, operational pollution that impacts fisheries, tourism, coastal waters, marine habitats, and human health in nearby lands can be legally controlled under coastal state jurisdiction.[1621]

When pollution operations violate domestic norms or when foreign ships affect their maritime environment by releasing pollutants or emissions into jurisdictional zones, coastal states may additionally enforce their laws through administrative sanctions or criminal or environmental measures.

4.3.4 Monitoring, Reporting, and Detection

Legal instruments commonly mandate ships to maintain logs and records, such as the BWM Convention's ballast water treatment logs, Annex VI's record keeping for air emissions, and MARPOL's Oil Record Book, Garbage Record Book, and Sewage Record Book.

Although monitoring and detection have previously been inadequate, improvements are now being made. Emissions (NO_2 plumes, sulphur infractions) and illicit discharges are being detected using remote sensing (satellite photography), aerial surveillance, drones, automated identification systems (AIS), and machine learning methods.[1622] For example, research has detected unusual NO_2 emissions from ships using satellite data (TROPOMI).

Similarly, methods that combine blockchain-based auditing frameworks with IoT

[1619] Flag State Explained: What It Means and Why It's Crucial in Maritime Law, Lmitac, https://www.lmitac.com/articles/flag-state-explained (last visited Oct. 6, 2025).

[1620] What Is Port State Control (PSC)?, MarineGyaan, https://marinegyaan.com/what-is-port-state-control-psc/ (last visited Oct. 6, 2025).

[1621] Diesel Ship, Coastal State Jurisdiction, Diesel Ship (May 14, 2019), https://dieselship.com/management/coastal-state-jurisdiction/.

[1622] International Convention for the Prevention of Pollution from Ships (MARPOL), https://www.imo.org/en/about/conventions/pages/international-convention-for-the-prevention-of-pollution-from-ships-(marpol).aspx (last visited Oct. 6, 2025).

sensors onboard have been proposed to provide transparency and real-time compliance monitoring.

4.3.5 Liability, Compensation, and Penalties

Liability regimes may be triggered in cases when infractions result in damages. The Bunker Convention for fuel oil pollution, the HNS for hazardous and noxious chemicals, and the CLC (Civil Liability Convention) for oil pollution damage are a few examples. In addition to establishing shipowner accountability, these treaties offer financial compensation mechanisms (such as the IOPC Funds under oil pollution liability). Penalties for non-compliance include fines, ship detention, certificate revocation, and in extreme or deliberate situations, criminal penalties under national laws.

4.3.6 Audits, Certification, and Institutional Mechanisms

The structure for certification and auditing adds another level of enforcement. One such tool is the IMO Member State Audit Scheme (IMSAS). It mandates that member nations submit to audits regarding the efficiency with which they carry out their responsibilities under mandatory IMO instruments, such as MARPOL.

These audits help identify areas that require technical assistance by exposing weaknesses in law, enforcement, implementation, and authority delegation. As of March 2023, for instance, 100 of the 175 Member States of the IMO had undergone IMSAS audits.

Additionally, persistent deficiencies (in pollution prevention, flag state implementation, port state management, etc.) are regularly noted and used to plan capacity building during Technical Cooperation Committee sessions.

5. ENVIRONMENTAL IMPACT OF OIL SPILL

Accidents involving oil spills have caused death, destruction of the environment, monetary losses, instability in society, and even political unrest. Oil spills into the ocean have distinct effects on the coastal ecosystem and the aquatic environment. Organisms are killed by oil-contaminated food and habitat. Oil spills may have a direct or indirect effect on the growth, behaviour, and reproduction of living things. According to estimates, the British Petroleum Gulf of Mexico incident killed 47 mammals, 400 sea turtles, and 997 birds.[1623]

The toxicity of the aromatic hydrocarbon compound alters the ecosystem after the oil spill. Physical smothering has a detrimental effect on the organism, just like many chemical processes do. Exposure to oil either kills living things or has a number of less serious negative effects on their health. The most hazardous chemicals are those found in oil, such as PAHs (Poly Aromatic Hydrocarbons), which can persist in the environment for decades. Even after sixteen years since the Exxon Valdez oil spill, sediments still contained traces of slightly weathered oil. Because of its rapid entry into the food chain and greater toxicity doses, PAH (poly aromatic hydrocarbon) is carcinogenic, this is also called the Biomagnification process.

5.1 Effect on fish:

Water contaminated with oil reduces the hatching of fish eggs and affects reproduction. There are sub lethal effects of oil exposure, which are seen widely in laboratory experiments. The Adzigbli and Yuewen, (2018) suggested that oil contaminated water develops morphological deformities, reduced growth rates, habitat degradation, loss of hatching ability of eggs, fouling of gill structures in Fish population. The oil chemicals are mutagenic and carcinogenic; it could induce disease in humans. Consumption of oil contaminated fish is also fatal for living organisms.[1624]

[1623] Environmental Effects - ITOPF, https://www.itopf.org/knowledge-resources/documents-guides/environmental-effects/ (last visited Oct. 6, 2025).
[1624] National Oceanic and Atmospheric Administration US Department of Commerce, How Does Oil Impact Marine Life? https://oceanservice.noaa.gov/facts/oilimpacts.html (last visited Oct. 6, 2025).

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5.2 Effect on Birds:

The repeated exposure of oil to sea birds has sub-lethal effects like deteriorating their health and declining reproductive capacity at a population level. The migratory and shorebirds also get affected by contaminated habitat, which changes their survival rate and reproduction. The Exxon Valdez oil spill killed almost 250,000 to 500,000 seabirds, shorebirds and Bald Eagles. In the Torrey Canyon tanker oil spill (1967), it is estimated that more than 25000 birds and many marine organisms were killed. Study reported that around 30,000 birds of Cormorants and Grebes species were affected by the Gulf war spill incident.[1625]

5.3 Effects of oil on shoreline habitat:

The spilled oil harms the shoreline vegetation and animals. The rocky beach is not sensitive to oil because usually rocky shoreline has got less vegetation by numbers, and the wave cleans the oil from the rocky bed easily. When the beach is sandy, oil quickly penetrates the sediments; it stays a long time in the soft surface layer of ground. The species who live in this contaminated sandy habitat face threat to health and life. Plant community at such contaminated shore is affected in terms of inhibition of the growth in roots, absorption capacity, and decreasing leaf numbers.

The grass-like vegetation inside the water and small grass species near shore come under threat due to inhibition of sunlight absorption due to blockage of stomata, which affects photosynthesis. The crude oil contamination induces abiotic stresses in plants. Animals are also in danger of eating contaminated prey. The contaminated habitat affects their offspring and eggs too. It has been found that when the seabed is oiled, the plant species rapidly diminishes by numbers. The burrowing animals and the root system in anoxic mud get contaminated easily. Various species of invertebrates, herbivores, Amphipoda, and crustacean's species are most affected by the oil spill.

It was reported that the spilled oil affected the subtidal Posidonia/Cymodocea (Seagrass) beds, deep-sea benthic community, and associated commercial fisheries. If the adjacent coastline of spill location consists of cobble, gravel, or even coarse sand, the oil may go into the underlying layer of those with tidal water. In the case of sheltered tidal flats, mangrove, and salt marshes, the oil quickly settles into the mud.

5.4 Effects on Mammals:

The marine Whales, Dolphins, Sea Otters and Seals are mostly affected by oil spill incidents. The oil contaminated water troubles the breathing process in Whales and Dolphins, by making oil clog, which may block the blowhole passage in such animals. Sea Otters and Seals have fur in their body, so they get hypothermia when the fur gets coated with the oil. Thousands of Sea Otters, hundreds of Harbor seals, many Killer Whales, including some river Otters, were killed in the Exxon Valdez oil spill. Years after this incident, these species still had higher death rates and declining growth rates.

5.5 Effect on beaches and sea:

The beaches affected by oil spill lose their scenic beauty. Activities like fishing, boating, bathing, diving all are prohibited around the beach. It affects tourism leading to economic loss for the affected country. The impacts are mostly for a short duration until the cleanup task is completed fully.

6. MAJOR OIL SPILL INCIDENTS INVOLVING OIL TANKERS

Marine oil spills can be in the form of few barrels to thousands of barrels. Marine oil spills are more damaging than the inland oil spill as they can spread to a larger area as thin films and then can damage the coast of beaches. The volume of oil spills is not always a measure of the severity of the damage. The geographical location of the discharge and sensitivity of the nearby shore is also crucial. It has been seen

[1625] Mason D. King, John E. Elliott & Tony D. Williams, Effects of Petroleum Exposure on Birds: A Review, 755 Sci Total Environ 142834 (2021).

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that a smaller amount of the spill had a more damaging impact than large spills, depending on the distance of the coast, wind, wave condition, type of Some of the major marine oil spills around the world.

6.1 Torrey canyon:

The first known big offshore oil spill happened in 1967 when super tanker Torrey Canyon ran aground on a reef off Isles of Scilly of Cornwall. It was the world's first major super tanker disaster. The oil spilled to beaches (approx. 200 km of Cornish coast) in southern England, an estimation suggests around 25-36 million gallons of crude oil spilled due to the accident.[1626]

6.2 Deepwater horizon:

Gulf of Mexico oil spill or BP oil spill, one of the largest in the oil and gas industry, occurred in 2010 when there was a blow out at BP's rig Deepwater Horizon. The rig was drilling Macondo prospect located in the deep-water region of GOM, USA. The accident killed 11 crew members of the platform. Initially, the oil spill was in the range of 12000-19000 barrels per day, which had later increased to more than 50,000 barrels per day. The official estimation shows total discharge at 4.9 million barrels (210 million US gal) of crude into the sea. This spill formed an oil slick, covering more than 112,000 Sq km on the ocean's surface. The spill affected 2100 km of shoreline, including beaches, marshes, wetlands, and estuaries, which are essential habitats and nursery areas. The toxicological effect of oil exposure has been found in different species of phytoplankton, invertebrates, fish, birds, sea turtles, mammals.[1627]

6.3 Gulf war:

One of the most massive oil spills in history occurred not because of an accident, but due to a War, During the Gulf war in 1991, Iraqi forces put oil wells in the fire while withdrawing from Kuwait. An astounding amount of oil was dispersed into the Persian Gulf, affecting thousands of fishes and marine mammal. It was estimated that around 10.8 million barrels of oil released into the ocean. A detailed assessment showed that there was a significant impact incurred on the marine and terrestrial environments. Some adverse effects were on soil, groundwater, terrestrial and marine ecology, marine quality, and air pollution.[1628]

6.4 The Ixtoc I:

Blow out in oil well Ixtoc I (semi-sub drilling rig Sedco135 at a water depth of 50m), in the bay of Campeche of Gulf in 1979, resulted in this massive oil spill. More than 3.4 million barrels of crude oil liberated to the nearby sensitive ecosystem. Various marine mammals, shrimp, card, turtles, birds were affected because of the spill. The impacted area hosts nesting sites for Kemp's Ridley turtles, which are classified as endangered species.[1629]

6.5 Atlantic Empress 1979:

The collision between two super tankers, the Atlantic Empress and Aegean Captain, resulted in one of the most massive oil spills offshore. The accident occurred off the coast of Tobago, in the Caribbean Sea in July 1979. About 88.3 million gallons (287,000 metric tons) of crude oil spilled into the water, impacting marine life. Twenty-six crew members of Atlantic Empress lost their lives in this unfortunate event. No detailed environmental study is available to discuss the extent of the damage.

6.6 Exxon Valdez:

Exxon Valdez is a well-known incident in oil spill history, which happened in Alaska in 1989. When Exxon Valdez, an oil tanker hit Prince William Sound's Bligh reef at a location around

[1626] Remembering the Torrey Canyon Oil Spill | OSRL News, Osrl, http://www.osrl.com/media/news/remembering-the-torrey-canyon/ (last visited Oct. 6, 2025).
[1627] Deepwater Horizon | Florida Department of Environmental Protection, https://floridadep.gov/wra/deepwater-horizon (last visited Oct. 6, 2025).h
[1628] AESG, Oil Spills in the Arabian Gulf: A Case Study and Environmental Review - Engineering Consultant | Specialist Consultancy, https://aesg.com/perspective/oil-spills-in-the-arabian-gulf-a-case-study-and-environmental-review/ (last visited Oct. 6, 2025).
[1629] Ixtoc I Oil Well: Oil in the Ocean, https://www.whoi.edu/oil/ixtoc-I (last visited Oct. 6, 2025).

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2.4 km west of Tatitlek, Alaska. The spill amount was nearly 11 million gallons (37,000 metric tons) crude oil. The contaminated area was approximately 1990 km along the shoreline of Prince William Sound. Around 250,000 sea birds,1800 sea otters, and 302 harbour seals were dead only after some days of the incident.

6.7 ABT Summer:

In 1991, the oil tanker ABT Summer exploded and caught fire at about 700 nautical miles off the Angolan coast. Approximately 51-78 million gallons of oil spilled into the sea. The oil spread around 80 square miles in the water surface with a very prominent visible slick. The tanker was burning until three days after the incident, but it was reported that marine environment impact was less as the spill occurred in the high sea and crude oil got dispersed fully.[1630]

6.8 Castillo de Bellver:

The Spanish tanker Castillo de Bellver caught fire and met an accident at Saldanha Bay off Cape Town, South Africa, in 1983. Around 79 million gallons of light crude oil spilled into the water due to this accident. The accident happened in an environmentally sensitive area, impacting the breeding season of sea birds, fish populations, and sea birds to a great extent.

6.9 Amoco Cadiz:

In 1978, the oil tanker Amoco Cadiz ran aground due to storm and started spilling the crude oil off the coast of Brittany, France. Almost 76 beaches were affected at that time and killed the marine life covering the slick oil area of 18 miles with 80 miles length.[1631] The US NOAA (National Oceanic and Atmospheric Administration) estimates that the total oil spill amounted to 1,604,500 barrels or 220,880 metric tons of oil.

6.10 MT Haven:

MT Haven, a VLCC (Very large crude carrier) loaded with crude oil, exploded off the coast of Genoa, Italy, in 1991. This incident resulted in spilling of around 1 million barrels (50,000 tonnes) of crude oil into the Mediterranean Sea. The accident occurred when the tanker was unloading crude at the floating platform. The impact of this oil spill could be observed almost for 12 years in the nearby region as per some reports.[1632]

6.11 Odyssey Oil Spill:

Odyssey, a Liberian tanker, exploded off the coast of Canada in November 1988.About 132,157 tons (43 million gallons) of oil spilled into water, impacting marine life and habitat. After the ship sunk, the spill covered an area of more than 30 square miles. Twenty-seven crew members died in this incident, but fortunately, less oil reached the shore due to the current direction at that time.

6.12 Sanchi oil spill:

This recent oil spill happened in 2018 due to the Sanchi oil tanker collision in the East China Sea. This Iranian tanker carrying 136,000 metric tons of natural-gas condensate sank near Japan's Ryukyu Islands after burning and drifting for over a week. None of its 32 crew members survived this incident. Oil slicks covered 39 square miles, and about 1900 tons of bunker oil and lots of condensates spilled into the sea.[1633]

7. TECHNOLOGICAL RESPONSES TO OIL SPILLS

Over the years, significant advancements have been made in the technology used to respond to oil spills. The key objective of any oil spill response is to minimize the environmental damage by containing and removing the oil as quickly as possible. Early response strategies include the use of booms and skimmers, which physically contain and

[1630] ABT SUMMER, off Angola, 1991, https://www.itopf.org/in-action/case-studies/abt-summer-off-angola-1991/ (last visited Oct. 6, 2025).

[1631] maritime Cyprus, Flashback in Maritime History: AMOCO CADIZ Oil Spill 16 March 1978, Maritime Cyprus (Mar. 14, 2025), https://maritimecyprus.com/2025/03/14/flashback-in-maritime-history-amoco-cadiz-oil-spill-16-march-1978-8/.

[1632] HAVEN, Italy, 1991, https://www.itopf.org/in-action/case-studies/haven-italy-1991/ (last visited Oct. 6, 2025).

[1633] MT Sanchi, Cedre, https://wwz.cedre.fr/en/Resources/Spills/Spills/MT-Sanchi (last visited Oct. 6, 2025).

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collect the oil, and dispersants, which break up the oil into smaller droplets. However, the effectiveness of these methods depends on the conditions of the water, the type of oil involved, and the time elapsed since the spill.

In more recent years, innovations in oil spill response have focused on improving oil spill detection and monitoring. Remote sensing technologies, such as satellites and drones, have made it easier to detect spills from great distances and assess their size and movement in real time. Additionally, the development of bioremediation techniques, which use microorganisms to break down the oil, holds promise for cleaning up oil spills more effectively in some cases.[1634]

Despite these advancements, the ability to fully mitigate the effects of a major oil spill remains limited. The 2010 BP oil spill, for instance, highlighted the challenges of responding to a spill in deepwater environments. Attempts to stop the flow of oil were delayed, and although many of the immediate responses were effective, the long-term environmental consequences were more difficult to manage.

8. PREVENTING FUTURE OIL SPILLS

Preventing oil spills before they occur is the most effective strategy for minimizing their impact. Governments and organizations have enacted stringent regulations to improve the safety of oil drilling and transportation operations. The Oil Pollution Act (OPA) of 1990, for example, was a major step in improving the U.S.'s ability to respond to and prevent oil spills. It mandates the use of double-hull tankers to reduce the likelihood of spills, requires oil companies to have spill response plans in place, and provides funding for spill cleanup.[1635]

Additionally, the international community has recognized the need for cooperative action. The International Maritime Organization (IMO) has adopted regulations to improve the safety of oil transport and prevent marine pollution from oil spills. However, enforcement remains a challenge, particularly in countries with less stringent regulations or inadequate enforcement mechanisms.

MARPOL Annex VI Sulphur Emissions: Global Enforcement of Fuel Sulphur Limits

Enforcement became a test of how successfully flag states, port states, and monitoring systems functioned when stricter sulphur fuel limitations under MARPOL Annex VI went into effect globally (with stricter limits in Emission Control Areas and globally starting in 2020). Older ships or those flying flags of convenience were more likely to be found non-compliant; some governments and regions with strong port state control (Northern Europe, for instance) have demonstrated higher compliance rates.[1636] Research indicates that sulphur compliance inspection rates are still low in many ports, and where inspections do occur, fuel sampling, monitoring, and trained personnel are essential for identifying infractions.

INTERPOL / Global Operations: Operation "30 Days at Sea"

Enforcement of maritime pollution has been the focus of coordinated Interpol activities. In "Operation 30 Days at Sea 3.0" (March 2021) authorities in 67 nations carried out over 34,000 inspections internationally and identified approximately 1,600 marine pollution offenses, ranging from illegal dumping to garbage trafficking. These kinds of activities demonstrate how enforcement can result in substantial detection and legal action when it is well-coordinated. On the other hand, follow-up

[1634] Committee on the Effects of the Deepwater Horizon Mississippi Canyon-252 Oil Spill on Ecosystem Services in the Gulf of Mexico et al., Oil Spill Response Technologies, in An Ecosystem Services Approach to Assessing the Impacts of the Deepwater Horizon Oil Spill in the Gulf of Mexico (2013), https://www.ncbi.nlm.nih.gov/books/NBK201624/.

[1635] Oil Spill Prevention, Preparedness and Response: What to Know, https://int-enviroguard.com/blog/oil-spill-prevention-and-preparation/ (last visited Oct. 6, 2025).

[1636] International Convention for the Prevention of Pollution from Ships (MARPOL), https://www.imo.org/en/about/conventions/pages/international-convention-for-the-prevention-of-pollution-from-ships-(marpol).aspx (last visited Oct. 6, 2025).

(prosecution, long-term compliance change) usually takes longer.[1637]

9. INDIA: LEGAL & ENFORCEMENT LANDSCAPE

India, as a signatory to major international maritime conventions such as UNCLOS and MARPOL, plays a proactive role in regulating operational pollution from ships. The country has incorporated MARPOL provisions into its national legislation through the Merchant Shipping Act, 1958, and its various amendments, enabling enforcement of pollution control measures across Indian ports and territorial waters. The Directorate General of Shipping (DGS) and the Indian Coast Guard are the primary agencies responsible for monitoring compliance, conducting inspections, and taking punitive action against violators. India has also established Port Reception Facilities (PRFs) at major ports to handle ship-generated waste, although there remain gaps in coverage and capacity at smaller ports. Additionally, India participates in regional initiatives like the Indian Ocean Memorandum of Understanding (IOMOU) on Port State Control, strengthening cooperative enforcement efforts across the Indian Ocean Region. Through ongoing investments in maritime infrastructure, legal reforms, and surveillance technology (e.g., coastal radars and vessel tracking systems), India is working to enhance its capability to combat marine pollution, though challenges remain in enforcement consistency and inter-agency coordination.[1638]

10. CONCLUSION

Operational pollution from ships poses a persistent threat to marine ecosystems, coastal communities, and global environmental health. While comprehensive legal instruments like MARPOL and UNCLOS provide a solid foundation, enforcement remains uneven due to gaps in monitoring, jurisdictional complexities, and inconsistent implementation among states. India's efforts—anchored in legal reforms, institutional development, and international cooperation—highlight the growing commitment of developing maritime nations to uphold marine environmental standards. To achieve meaningful reduction in ship-sourced pollution, global efforts must prioritize capacity building, technological innovation, and stronger accountability mechanisms across flag, coastal, and port states. A collaborative, well-resourced, and transparent enforcement regime is essential to ensure that operational pollution is not only regulated on paper but effectively deterred in practice.

[1637] Operation 30 Days at Sea 3.0 Reveals 1,600 Marine Pollution Offences Worldwide, https://www.interpol.int/en/News-and-Events/News/2021/Operation-30-Days-at-Sea-3.0-reveals-1-600-marine-pollution-offences-worldwide (last visited Oct. 6, 2025).
[1638] Steps Taken for Prevention and Control of Pollution from Ships, https://www.pib.gov.in/www.pib.gov.in/Pressreleaseshare.aspx?PRID=1605383 (last visited Oct. 6, 2025).