**Marine Pollution**

  10th February 2020

Introduction

Pollution is defined in the UN Convention on the Law of the Sea as ‘the introduction by man, directly or indirectly, of substances or energy into the marine environment, including estuaries, resulting in such deleterious effects as harm to living resources, hazards to human health, hindrance to marine activities, including fishing, impairment of quality for use of sea water and reduction of amenities’.[1](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-1-54).

A ship in the water

Description automatically generated*IMO helping to mitigate the impacts of MV Wakashio oil spill in Mauritius by*[*International Maritime Organisation*](https://www.flickr.com/photos/imo-un/50236896003/in/photolist-2jxgdXn-2kRGv8M-2jxkEac-2kRFXQ5-2jvT97Q-2jxjxG3-2jxjxD7-2jxgdY4-2jxgdYu-2jxgdYj-2jwMGVh-2juCYyM-xcFKRy-xrYFG1-2jszoEx-mg4gr-6DKnJ6-2kRMEKf-2kRHcMd-2kRHcQe-UmjfNq-2juMmfj-2jszjwH-2jsC7uZ-2jwMDyH-2jszk37-2jszqVu-2jszkfg-2jszkBZ-oRHAV8-p9bPgd-p9bJ5G-2jx3x9g-2jx3Emn-oRHpYt-p9bRT7-oRHYd9-oRHXA7-2jszpkk-2jsznCh-2jsDrMf-2jsznY7-2jsC9Ls-2jszryU-2jsDvSe-2jsCbeC-2jvN2YS-2kFCmMk-2juJLEp-2juJKSs)*(Attribution 2.0 Generic (CC BY 2.0))*

Characteristics

*Sources of pollution*

Marine pollution can be caused by numerous different materials, both solid and liquid, with common sources deriving from:

* dredging by-products
* industrial, chemical and radioactive waste
* sewage sludge
* mining and ore by-products
* ship-based black and grey water
* oil and chemical spills
* plastics and other forms of marine litter such as Abandoned, Lost, or Otherwise Discarded Fishing Gear (ALDFG)
* shipbreaking activities in coastal areas

The silt and sand that builds up in rivers, canals, ports, or harbours is dredged and often dumped into the ocean. Dredging is conducted not only to clear space for the entry of ships and flowing of rivers, but also to remediate areas which are contaminated by industrial contaminants such as hydrocarbons, pesticides and heavy metals.[2](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-2-54) Some estimates suggest that as much as 80% of solid waste dumped into the ocean originates as dredging by-product.[3](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-3-54).

Some forms of marine pollution originate from land-based activities. Industrial by-products for example can be directly dumped at sea, introduced into the ocean through outflow pipes, or through run-offs from rivers and streams. Industrial waste can include materials such as pesticides and fertilisers from farming and industrial chemicals from factories and other land-based industry such as mining.[4](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-4-54) Historically, radioactive waste originating from nuclear power plants or medical and research activities was also dumped in the oceans. However, the last known official dumping operation of radioactive waste at sea was took place in 1982, making it a less significant source of pollution today. Raw sewage can be dumped directly into the ocean from outflows, or treated sewage dumped at specific sites.[5](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-5-54). Plastic waste is also recognised as increasingly significant problem and is discussed in its own entry elsewhere on this site.

Many sources of marine pollution result specifically from shipping. Waste from shipping activities includes the release of black water, grey water, and ballast water into the oceans.[6](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-6-54) This is referred to as operational pollution.[7](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-7-54) Black water is the direct discharge of sewage sludge from the vessel itself.[8](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-8-54) Grey water is that which has been used to clean or fill storage containers, or from kitchens, laundry and showers, which is then dumped at sea.[9](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-9-54) Ballast water is water that fills compartments to help stabilise and balance a ship, which is then discharged. Litter from ships can also be dumped directly into the sea.

While technological measures can reduce the contamination of the water in most modern ships, these processes are not 100 per cent effective. Safe disposal facilities for shipping waste are provided at many ports, though the quality of these facilities vary by location. They can also be expensive and time consuming to use, which can lead to less scrupulous shipping operators discharging waste directly into the seaefn\_note][Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1); [Arguello 2020](https://www.routledge.com/Marine-Pollution-Shipping-Waste-and-International-Law/Arguello/p/book/9781032240671)[/efn\_note]

Oil pollution occurs through the discharge of contaminated ballast water [10](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-10-54), or during spillages when ships are bunkering, whether in port or through ship to ship transfers. Large scale oil spills occur due to accidents such as sinking ships or damaged oil platforms and tend to gain the most public attention.[11](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-11-54)

Containers lost at sea from ships are an increasing common form of marine pollution. Containers can fall off of ships due to stormy weather, ship design, propulsion issues, and inappropriate stowage or stacks.[12](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-12-54) This is problematic because a variety of different pollutants can be transported in containers.

*Criminalisation*

Not all marine pollution is illegal and some is considered relatively harmless if properly treated or undertaken in a controlled manner. What counts as illegal pollution is a complex question. Some polluting activities are explicitly prohibited by international or domestic law. Other activities are not explicitly prohibited but still cause significant damage to both coastal communities and marine ecosystems. Some illegal polluting activities are highly organised while others are ad hoc, with varying degrees of intentionality involved, ranging from negligence to the wilful evasion of regulation for profit.

While domestic regulations differ, dredging for example is not generally criminalised soo long as it follows regulatory procedures such as using specific dredge sites and gaining the required licenses.[13](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-13-54) These legal sites are usually chosen after careful selection in order to minimise impacts and harms. Dumping at sea is considered a requirement due to the frequent absence of land based alternatives.[14](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-14-54)

There are few detailed analyses of illicit dredging and dumping though there is plentiful evidence these activities take place.[15](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-15-54) There have been numerous documented cases of illegal dumping that resulted from negligent practices such as miscommunication or a lack of internal compliance for example.[16](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-16-54) There are also cases which exhibit higher degrees of organisation in terms of actors involved and wilful attempts to evade enforcement. For example, in the Philippines the dumping of dredging by-product results from illegal black sand dredging, with a number of transnational actors are involved.[17](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-17-54)

The disposal of industrial waste is often highly regulated, and evading these regulations often implies organised criminal involvement. This is particularly so in the case of radioactive or hazardous waste dumping. While such activities are difficult to verify, there is evidence that radioactive and toxic waste was illegally dumped off the coast of Somalia in the wake of the collapse of the Somali state in the 1990s.[18](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-18-54) There have also been accusations of ships full of waste being scuttled deliberately in Somali waters. Highly organised groups such as the Italian Mafia appear to have been involved, facilitated by corruption in both Italy and Somalia.[19](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-19-54) Similar activities are alleged to have taken place in the Mediterranean.[20](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-20-54)

Most countries ban discharge from mining sites into the sea, with the exceptions of Norway, Papua New Guinea, the Philippines, Indonesia, France, Turkey and Chile – though in many of these countries such activities are highly regulated. Even with bans on dumping, however, such practices do still occur.[21](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-21-54) They can also result from illegal mining, and therefore be part of broader and more organised criminal networks. An example of this was the mining of bauxite despite a moratorium on such activities in Malaysia, which led to run-offs being dumped into coastal waters.[22](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-22-54)

The disposal of sewage sludge at sea is generally legal so long as it meets UN guidelines on contamination limits. Sewage disposal is mostly well-regulated on land, meaning that contraventions tend to be due to negligence rather than intentionally organised. ‘Black water’ dumping from shipping is less easy to control, and may be illegally dumped at sea by unscrupulous shipping operators seeking to avoid the expense or delay of its safe disposal in port.

While oil spills generally result from accidents, they may be caused or exacerbated by various problematic practices, including criminal ones.[23](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-23-54) For example, the MV Wakashio spilled oil when it ran aground off the coast of Mauritius in 2021. The captain was found guilty of negligence having admitted being under the influence of alcohol at the time the incident occured.[24](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-24-54). Oil spills can also occur during other illicit activities such as illegal ship-to-ship transfers of oil or oil theft from ships.

For this and other forms of vessel source pollution, there may be further underlying practices which can sometimes amount to corporate crimes. These may include a lack of maintenance of critical equipment, poor structural quality of ships or infrastructure, or the implementation of unsafe cost-saving measures to increase profits.[25](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-25-54)

Scope

There has been little systematic research on the overall scope of illegal pollution. Instead, most analysis tends to focus on ad hoc cases which cannot be meaningfully extrapolated, or focus in on one particular form of pollution.

An indicative example is oil pollution. The International Tanker Owners Pollution Federation (ITOPF) maintains a database of oil spills.[26](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-26-54) It shows that in the 1970s, the annual average oil spill quantity was 78.8 occurrences per yer, but in the 2010s this decreased to 6.3 per year. However, the database does not cover other forms of oil pollution such as that occurring through ballast water discharge, port transfers, or ship-to-ship transfers.

Marine oil pollution remains a significant problem, despite indications that instances have declined since the 1970s. Between 2000-2010 for example ‘over 1 billion gallons of oil were spilled worldwide and 6 million tonnes per year entered the oceans’.[27](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-27-54) Unspoilt environments such as the Arctic may also become increasingly vulnerable to oil spills as human activity in these regions intensifies.[28](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-28-54)

One form of marine pollution that has increased significantly is shipping container losses. These are monitored by the World Shipping Council, who release an annual report on the issue.[29](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-29-54) Their 2021 report showed that average losses for the two-year period 2020-2021 increased to 3,113 from the 779 of the previous period. These figures may be an under-estimate because they only include data that is self-reported from World Shipping Council members.

Impact

The UN Group of Experts on the Scientific Aspects of Marine Pollution have argued that waste pollution at sea is problematic because it tends to occur close to the coast and where it becomes concentrated.[30](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-30-54) The impact of marine pollution however is well understood in general terms, but there have been few analyses of the impact of illegal pollution specifically.

*Marine Environment*

Most research focuses on the impact of pollution on the marine environment. For example, there are multiple studies that analyse the impact of dumping (and dispersal) of dredging and mining waste at sea.[31](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-31-54) Dumping and sewage disposal at sea can lead to significant sediment build-up which can smother marine habitats and destroy their ability to sustain life at various ocean depths.[32](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-32-54) In areas where dredged sediment has been dumped in the North Sea, research found a precipitous decline in marine organisms.[33](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-33-54) Dredging and sewage sludge also often contain large amounts of plastics – especially microplastics – which cause plastic pollution.[34](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-34-54)

Mining and dredging can also lead to increased toxicity in the marine environment. Yilmaz for example has shown that marine organisms exhibit signs of toxic and mutagenic effects from the pollutants accumulated in dredged sediment.[35](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-35-54) In areas of the North Sea where sediment has been dumped, toxin levels were found to be 2-3 times higher than areas that had not seen dredged dumping.[36](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-36-54) Studies focused on various sites in China, Korea, Brazil and the UK have seen increased concentrations of heavy metals.[37](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-37-54) While there appears to have been little immediate impact on the health of sea-life as a result, there are concerns that the effects of marine toxicity may be chronic rather than acute and only become apparent over the longer term.[38](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-38-54)

Oil spills impact the marine environment more directly.[39](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-39-54) By coating the marine environment, including sensitive areas such as mangroves and coral reefs, in viscous and toxic oil, they cause significant loss of life to marine wildlife and damage habitats.[40](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-40-54) This can have knock effects on the feeding, growth, development and reproduction of marine species, with impacts that spread beyond the location of the spill itself[41](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-41-54)

Ballast water dumping can discharge harmful alien aquatic organisms and pathogens into sensitive environments.[42](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-42-54) These alien organisms ‘may encounter no natural predators in their new environment and proceed to displace indigenous species’, or can spread disease.[43](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-43-54)

The dumping of sewage sludge can contribute to eutrophication – a process in which dissolved nutrients such as nitrogen can cause oxygen-depleting plants and bacteria to spread, with pathological effects on the wider environment through hypoxia.[44](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-44-54)

*Society*

Pollution can impact on coastal communities in multiple ways. By degrading the marine environment, pollution can cause the loss of jobs and income for those that depend on healthy seas. For example, the Exxon Valdez oil spill in Alaska in 1989, caused direct fisheries losses of USD$109.1 million and resulted in lost wages and employment for local fishers and firms.[45](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-45-54) The psychological impact of such events can be significant, with evidence of increased depression and anxiety in effected communities following large scale pollution incidents .[46](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-46-54)

Toxicity resulting from all forms of pollution can impact negatively on human health. [47](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-47-54) Clean-ups are also expensive. Exxon paid an additional $2.2 billion for clean-up operations, $1 billion to settle state and federal lawsuits, and $5.3 billion in punitive and compensatory damages to those harmed by the spill.[48](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-48-54) Some forms of pollution may pose navigational hazards. Shipping containers, for example, often float long distances and can be difficult to detect from the bridge of a ship.

*States*

Pollution impacts on states due to the costs that it can engender. Costs come in two forms. First, it damages industries that depend on the marine environment such as fishing or tourism, and with a negative impact on state revenue.[49](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-49-54) Second, states often have to bear the costs of clean-up operations, though these may later be covered by damages or insurance payouts.[50](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-50-54) These costs can be particularly problematic for small island developing states, whose economies are often dependent on the oceans and who are often located on busy shipping lanes where pollution incidents are more frequent.[51](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-51-54)

Linkages & Synergies

Pollution is linked to two other blue crimes. The first is waste trafficking, which can lead to various forms of waste being dumped in rivers or the ocean at destination. The second is illicit bunkering and oil smuggling, which can lead to an increased risk of oil pollution because of the unregulated and often unsafe manner in which it is carried out.

Responses

*International*

Marine pollution is regulated by the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (London Convention). These conventions have been relatively successful in monitoring and regulating polluting practices, including pollution that takes place through criminal negligence, though have had less impact on more organised or premeditated criminal dumping activities.[52](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-52-54)

The International Maritime Organization (IMO) also sets standards to try to prevent pollution incidents.[53](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-53-54) In 1992, the IMO recommended the mandatory adoption of double hulls for all oil tankers carrying heavy crude oil and fuel, and there has been a phasing out of single-hulled tankers since then.[54](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-54-54) It also passed the International Convention on Oil Pollution Preparedness, Response and Cooperation in 1990 which ‘promotes international cooperation and mutual assistance to prepare for and respond to major oil pollution incidents, and encourages countries to develop and maintain adequate capacity to deal with oil pollution emergencies’.[55](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-55-54) Other IMO guidelines cover issues such as the discharge of ballast water away from shore and the requirement for a ballast water management plan. [56](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-56-54)

In addition, the IMO oversees a compensation regime to both fund the restoration of polluted areas and act as a deterrent to potential polluters. It comprises the International Convention on Civil Liability for Oil Pollution Damage and the International Convention on Civil Liability for Bunker Oil Pollution Damage.[57](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-57-54) However, these measures apply primarily to marine rather than land-sourced pollution and are dependent on flag states being willing and able to ensure compliance.[58](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-58-54)

At the level of operational enforcement, INTERPOL engages in capacity building and technical support activities to support states in investigating cases of marine pollution. For example, they publish a Pollution Crime Forensic Investigation Manual to assist with environmental forensics.[59](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-59-54) The UN Office on Drugs and Crime also trains prosecutors to tackle marine pollution, and assists with the development of national frameworks to combat marine pollution.[60](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-60-54)

*Regional*

Various regional initiatives have been implemented on marine pollution and preparedness.[61](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-61-54) Examples include the Western Indian Ocean Island Oil Spill Contingency Planning and Western Indian Ocean Marine Highway Development and Coastal and Marine Contamination Prevention projects.[62](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-62-54) The European Maritime Safety Agency (EMSA) leads the European Union’s collective response to marine pollution, pooling resources and assisting member states in their own anti-pollution measures.[/efn\_note][Kramer 2007](https://link.springer.com/book/10.1007/978-3-540-73396-6); [EMSA 2014](https://www.emsa.europa.eu/opr-documents/action-plans/item/1961-action-plan-for-response-to-marine-pollution-from-oil-and-gas-installations.html)[/efn\_note]

*National*

Most countries regulate against marine pollution in some form or another and have contingency plans in place for pollution incidents. However, the strength of these measures can vary significantly between countries.

Even in countries with strong regulatory frameworks, a lack of compliance and enforcement prioritisation can limit responses.[63](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-63-54) Elsewhere, marine pollution may be treated as an administrative rather than a criminal issue, with two primary effects.[64](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-64-54) First, law enforcement agencies are not often sufficiently empowered to investigate and respond to incidents effectively. Second, a lack of sufficient sanction means it is often cheaper to infringe environmental regulations than it is to abide by them.[65](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-65-54)

Capacity issues can also limit some country’s responses. For example, the detection and monitoring of pollution events can be strengthened through the use of satellite imagery or automatic sensors.[66](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-66-54) However, these can be expensive technologies and are not easily available to all states.[67](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-67-54) Others may not have access to the necessary clean up equipment or expertise in the event of an incident at sea. These issues are intensified in remote locations such as the Arctic, or where countries have limited capacity such as the West Indian Ocean.[68](https://www.safeseas.net/evidence/2020/02/10/pollution/#easy-footnote-bottom-68-54)

List of References

1. [UN 1982](https://www.un.org/depts/los/convention_agreements/texts/unclos/part1.htm)
2. [Yilmaz et al. 2019](https://www.tandfonline.com/doi/abs/10.1080/10934529.2019.1631656?tab=permissions&scroll=top); [Norton & Rolfe 1978](https://www.cefas.co.uk/publications/techrep/tech45.pdf); [Moreira et al. 2021](https://www.sciencedirect.com/science/article/pii/S0013935120314225); [Wang & Leonard 2009](https://www.cambridge.org/core/journals/environmental-conservation/article/abs/dredging-pollution-and-environmental-conservation-in-the-united-states/D513F8FA3306F6B365DC7E9C626AE717); [Wenger et al. 2017](https://onlinelibrary.wiley.com/doi/full/10.1111/faf.12218)
3. [Lumsdaine 1976](https://heinonline.org/HOL/Page?handle=hein.journals/eclawq5&div=30&g_sent=1&casa_token=wxp2839PumoAAAAA:F0vh6ELwR0Q6wHvgkhzTA4fr3P8xMABUM7ZpOeFO6KigpZyHhdpkymCNBHfrQxvdfCMDHCg5&collection=journals); [Marine Bio n.d.](https://www.marinebio.org/conservation/ocean-dumping/); see also[Johnson & Lichtveld 2017](https://www.taylorfrancis.com/books/mono/10.1201/9781351228473/environmental-policy-public-health-barry-johnson-maureen-lichtveld)
4. [Frid & Caswell 2017](https://academic.oup.com/book/26583)
5. [Frid & Caswell 2017](https://academic.oup.com/book/26583)
6. [IMO n.d.](https://www.imo.org/en/OurWork/Environment/Pages/Sewage-Default.aspx); [Bascom 1974](https://www.jstor.org/stable/24950139#metadata_info_tab_contents); [Walker et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000309); [Hall 2021](https://www.cambridge.org/core/books/environmental-impact-of-ships/waste-and-sewage/E6DDF9E4B44B0857FBB5DE5D9B59D37B); [Peng et al. 2022](https://pubs.acs.org/doi/10.1021/acs.est.1c05446); [Yang 2011](https://www.sciencedirect.com/science/article/pii/B9780444522726003159); [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1); [Arguello 2020](https://www.routledge.com/Marine-Pollution-Shipping-Waste-and-International-Law/Arguello/p/book/9781032240671)
7. [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1)
8. [Hall 2021](https://www.cambridge.org/core/books/abs/environmental-impact-of-ships/waste-and-sewage/E6DDF9E4B44B0857FBB5DE5D9B59D37B)
9. [Hall 2021](https://www.cambridge.org/core/books/abs/environmental-impact-of-ships/waste-and-sewage/E6DDF9E4B44B0857FBB5DE5D9B59D37B)
10. [Yang 2011](https://www.sciencedirect.com/science/article/pii/B9780444522726003159); [Chen et al. 2019](https://www.sciencedirect.com/science/article/abs/pii/S095965261931090X); [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1); [Botello et al. 2021](https://www.routledge.com/Marine-Pollution-and-Climate-Change/Arias-Marcovecchio/p/book/9780367781910)
11. [Brisman et al. 2018](https://link.springer.com/book/10.1057/978-1-137-52986-2); [Ruiz et al. 2020](https://journals.sagepub.com/doi/abs/10.1177/0306624X20967950); [Chen et al. 2019](https://www.sciencedirect.com/science/article/abs/pii/S095965261931090X)
12. [Frey & De Vogelaere 2014](https://repository.library.noaa.gov/view/noaa/17410); [Wasalaski 2021](https://onepetro.org/SNAMESMC/proceedings-abstract/SMC21/1-SMC21/D011S001R004/470721); [Maritime Executive 2022](https://maritime-executive.com/editorials/what-happens-when-containers-are-lost-at-sea); [World Shipping Council 2022](https://www.worldshipping.org/news/world-shipping-council-containers-lost-at-sea-report-2022-update-published); [Mathias 2022](https://maritime.law.uq.edu.au/index.php/anzmlj/article/download/2264/2102)
13. [Norton & Rolfe 1978](https://www.cefas.co.uk/publications/techrep/tech45.pdf); [UK MMO 2019](https://www.gov.uk/guidance/deposits)
14. [Norton & Rolfe 1978](https://www.cefas.co.uk/publications/techrep/tech45.pdf)
15. [Zhang et al. 2018](https://journals.sagepub.com/doi/full/10.1177/1550147718818400)
16. [BBC 2015](https://www.bbc.com/news/uk-england-34054758)
17. [Chaussard & Kerosky 2016](https://www.mdpi.com/2072-4292/8/2/100/html); [Villanueva 2019](https://businessmirror.com.ph/2019/08/15/the-dark-side-of-black-sand-mining/)
18. [Greenpeace 2010](https://www.greenpeace.org/archive-italy/Global/italy/report/2010/inquinamento/Report-The-toxic-ship.pdf); [Herring & Funnell 2016](http://bit.ly/nuclearwastedumping); [Herring et al. 2020](https://www.tandfonline.com/doi/full/10.1080/23779497.2020.1729220); [Brisman et al. 2018](https://link.springer.com/book/10.1057/978-1-137-52986-2)
19. [Greenpeace 2010](https://www.greenpeace.org/archive-italy/Global/italy/report/2010/inquinamento/Report-The-toxic-ship.pdf)
20. [Greenpeace 2010](https://www.greenpeace.org/archive-italy/Global/italy/report/2010/inquinamento/Report-The-toxic-ship.pdf)
21. [Brisman et al. 2018](https://link.springer.com/book/10.1057/978-1-137-52986-2)
22. [Kuan et al. 2020](https://ideas.repec.org/a/eee/jrpoli/v66y2020ics0301420719307834.html)
23. [Brisman et al. 2018](https://link.springer.com/book/10.1057/978-1-137-52986-2)
24. [Nikkei Asia 2021](https://asia.nikkei.com/Spotlight/Environment/Mauritius-oil-spill-Japan-owned-ship-s-captain-sentenced-to-20-months)
25. [Brisman et al. 2018](https://link.springer.com/book/10.1057/978-1-137-52986-2); [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1)
26. [ITOPF n.d.](https://www.itopf.org/knowledge-resources/data-statistics/statistics/)
27. [Zhang et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000243)
28. [Johannsdottir & Cook 2019](https://www.sciencedirect.com/science/article/abs/pii/S0964569119300912); [Frid & Caswell 2017](https://academic.oup.com/book/26583)
29. [World Shipping Council 2021](https://www.worldshipping.org/news/world-shipping-council-containers-lost-at-sea-report-2022-update-published)
30. [Gray et al. 1991](https://www.sciencedirect.com/science/article/pii/0025326X9190211A)
31. [Herbich 1981](https://hero.epa.gov/hero/index.cfm/reference/details/reference_id/8281840); [Kim & Lim 2009](https://www.sciencedirect.com/science/article/pii/S0278434308000320); [Vagge et al. 2018](https://www.sciencedirect.com/science/article/pii/S0025326X1830571X); [Staniszewska & Boniecka 2018](https://www.sciencedirect.com/science/article/pii/S0025326X1830198X); [Cunning et al. 2019](https://www.sciencedirect.com/science/article/pii/S0025326X19303868); [Oh & Kim 2020](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7660325/)
32. [McKinnon 200](https://www.semanticscholar.org/paper/The-environmental-effects-of-mining-waste-disposal-McKinnon/ea900ab1d0ed12c4423c313da5dbd2c89ec2d721)2; [Shimmield et al. 2010](https://ramumine.files.wordpress.com/2010/09/complete-dstp-final-report_master-080610.pdf); [Cardoso-Mohedano et al. 2016](https://www.sciencedirect.com/science/article/pii/S0025326X16300662?via%3Dihub); [Silveira et al. 2017](https://www.sciencedirect.com/science/article/pii/S0025326X17302229); [Palanques et al. 2022](https://www.sciencedirect.com/science/article/pii/S0964569122000886); [Todd et al. 2015](https://academic.oup.com/icesjms/article/72/2/328/676320)
33. [Stronkhorst et al. 2003](https://www.sciencedirect.com/science/article/pii/S026974910200430X)
34. [IMO 2016](https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Marine%20litter%20review%20for%20publication%20April%202016_final_ebook_version.pdf)
35. [Yilmaz et al. 2019](https://www.tandfonline.com/doi/abs/10.1080/10934529.2019.1631656?tab=permissions&scroll=top)
36. [Stronkhorst et al. 2003](https://www.sciencedirect.com/science/article/pii/S026974910200430X)
37. [Rumney et al. 2015](https://www.sciencedirect.com/science/article/pii/S0025326X14008558); [Chung et al. 2017](https://www.sciencedirect.com/science/article/pii/S0025326X17306148); [Silveira et al. 2017](https://www.sciencedirect.com/science/article/pii/S0025326X17302229); [Chen et al. 2019](https://www.sciencedirect.com/science/article/pii/S0048969719305364?via%3Dihub#!)
38. [Wang et al. 2020](https://www.sciencedirect.com/science/article/pii/S0147651320312100); [Frid & Caswell 2017](https://academic.oup.com/book/26583)
39. [Kingston 2002](https://www.sciencedirect.com/science/article/abs/pii/S1353256102000518); [Jernelov 2010](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3357709/)
40. [Chilvers et al. 2015](https://www.sciencedirect.com/science/article/abs/pii/S0025326X15300345); [Zhang et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000243)
41. [Tansel 2014](https://www.sciencedirect.com/science/article/abs/pii/S2212420913000587)
42. [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1); [Walker et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000309); [Souissi et al. 2021](https://www.routledge.com/Marine-Pollution-and-Climate-Change/Arias-Marcovecchio/p/book/9780367781910); [DiBaccio et al. 2012](https://academic.oup.com/icesjms/article/69/3/483/597336); [Chan et al. 2015](https://scholar.google.com/scholar_lookup?title=Relative%20importance%20of%20vessel%20hull%20fouling%20and%20ballast%20water%20as%20transport%20vectors%20of%20nonindigenous%20species%20to%20the%20Canadian%20arctic&author=S.A.%20Bailey&publication_year=2015&pages=1230-1242); [Bailey 2015](https://scholarlypublishingcollective.org/msup/aehm/article-abstract/18/3/261/169202/An-overview-of-thirty-years-of-research-on-ballast?redirectedFrom=fulltext)
43. [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1); [Walker et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000309)
44. [Weis 2015](https://global.oup.com/academic/product/marine-pollution-9780199996681?cc=us&lang=en&); [Frid & Caswell 2017](https://academic.oup.com/book/26583)
45. [Dalton & Jin 2010](https://pubmed.ncbi.nlm.nih.gov/20797735/)
46. [Johannsdottir & Cook 2019](https://www.sciencedirect.com/science/article/abs/pii/S0964569119300912)
47. [Bruederlea & Hodlera 2019](https://www.pnas.org/doi/10.1073/pnas.1818303116); [Laffon et al. 2016](https://pubmed.ncbi.nlm.nih.gov/27221976/)
48. [Dalton & Jin 2010](https://pubmed.ncbi.nlm.nih.gov/20797735/)
49. [Zhang et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000243)
50. [Johannsdottir & Cook 2019](https://www.sciencedirect.com/science/article/abs/pii/S0964569119300912); [Zhang et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000243)
51. [UN Secretariat 2022](https://sdgs.un.org/sites/default/files/2022-05/ID_1_Addressing_marine_pollution.pdf)
52. [IMO 2016](https://wwwcdn.imo.org/localresources/en/OurWork/Environment/Documents/Marine%20litter%20review%20for%20publication%20April%202016_final_ebook_version.pdf); [Birchenough & Haag 2020](https://brill.com/view/journals/ocyo/34/1/article-p255_11.xml?language=en); [Zhou and Zhang 2017](https://brill.com/downloadpdf/journals/apoc/2/2/article-p247_247.xml); [Rakestraw n.d.](https://www.informea.org/en/literature/open-oceans-and-marine-debris-solutions-ineffective-enforcement-marpol-annex-v); [Mattson 2006](https://www.tandfonline.com/doi/full/10.1080/13880290600728195?casa_token=MEYYHr5d_j8AAAAA:TUxUeLo__QG3xUlGohvrQKQfTDyQY0zk9VWf5yJI_qREGadU8vp4lpquxze_oe8c4VMRliC_UYHf); [Peet 1992](https://heinonline.org/HOL/LandingPage?handle=hein.journals/ljmc7&div=48&id=&page=); [Mantoju 2021](https://www.tandfonline.com/doi/full/10.1080/25725084.2021.1965281); [Hong & Lee 2015](https://www.sciencedirect.com/science/article/pii/S0308597X15000184); [Stokke 1998](https://www.taylorfrancis.com/chapters/edit/10.4324/9781315066547-5/beyond-dumping-effectiveness-london-convention-olav-schram-stokke); [Curtis 1985](https://heinonline.org/HOL/LandingPage?handle=hein.journals/envlnw15&div=37&id=&page=); [Lagring et al. 2012](https://www.sciencedirect.com/science/article/pii/S0025326X11006217?casa_token=eM5pKOZJ4voAAAAA:DLc_cs3mdmtHvbOmMS_vChFDz9LoU6vcK0JQ0t-3JBbnxhXUfMFmQDBRTIHFk1W7kv3ztrLgSw); [Karim 2010](https://brill.com/view/journals/nord/79/2/article-p303_4.xml?casa_token=zd11X465SkcAAAAA:7v_ZqENSZorPP9cN9BCuY9h2-R6bysJ9j35whTtVSpkk_4OI5BQ3IvCEdnvSzuE-3z_9jNnW); [Shi & Zhang 2021](https://www.routledge.com/Marine-Pollution-and-Climate-Change/Arias-Marcovecchio/p/book/9780367781910); [Walker et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000309)
53. [Mensah 2007](https://link.springer.com/book/10.1007/978-3-540-73396-6)
54. [Chen et al. 2019](https://www.sciencedirect.com/science/article/abs/pii/S095965261931090X)
55. [Chen et al. 2019](https://www.sciencedirect.com/science/article/abs/pii/S095965261931090X)
56. [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1)
57. [Ong 2002](https://academic.oup.com/book/5014/chapter-abstract/147523518?redirectedFrom=fulltext); [Ehlers 2007](https://link.springer.com/book/10.1007/978-3-540-73396-6); [Wolfrum 2007](https://link.springer.com/book/10.1007/978-3-540-73396-6); [Jacobbson 2007](https://link.springer.com/book/10.1007/978-3-540-73396-6); [Zhu 2007](https://link.springer.com/book/10.1007/978-3-540-73396-6)
58. [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1); see also: [Arguello 2020](https://www.routledge.com/Marine-Pollution-Shipping-Waste-and-International-Law/Arguello/p/book/9781032240671)
59. [INTERPOL 2014](https://www.interpol.int/content/download/5171/file/INTERPOL%20Pollution%20Crime%20Forensic%20Investiation%20Manual%20-%20volume%202%20EN.pdf)
60. [UNODC n.d.](https://www.unodc.org/documents/Maritime_crime/UNODC_Approach_to_Crimes_that_Affect_the_Environment.pdf); [n.d.](https://sdgs.un.org/partnerships/unodc-commits-supporting-member-states-prevent-address-and-respond-incidents-marine)
61. [Johannsdottir & Cook 2019](https://www.sciencedirect.com/science/article/abs/pii/S0964569119300912); [Steen et al. 2003](https://meridian.allenpress.com/iosc/article/2003/1/29/198382/Global-Challenges-to-Preparedness-and-Response); [Kim 2015](https://www.tandfonline.com/doi/abs/10.1080/00908320.2014.929470)
62. [Bueger & Edmunds 2020](https://www.orfonline.org/expert-speak/mauritius-oil-spill-reveals-weakness-of-maritime-security-architecture-in-the-western-indian-ocean/)
63. [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1); [Walker et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000309)
64. [Brisman et al. 2018](https://link.springer.com/book/10.1057/978-1-137-52986-2)
65. [Brisman et al. 2018](https://link.springer.com/book/10.1057/978-1-137-52986-2); see also [Tan 2009](https://www.cambridge.org/core/books/vesselsource-marine-pollution/0C89B381CA96F4652C9FB464E1ABB4D1); [Frid & Caswell 2017](https://academic.oup.com/book/26583); [Walker et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000309); [Friehe & Langlais 2017](https://www.sciencedirect.com/science/article/abs/pii/S0095069616300705); [Hall 202](https://www.cambridge.org/core/books/abs/environmental-impact-of-ships/waste-and-sewage/E6DDF9E4B44B0857FBB5DE5D9B59D37B)1
66. [Kubat et al. 1998](https://link.springer.com/article/10.1023/A:1007452223027); [Solberg et al. 1999](https://ieeexplore.ieee.org/document/774704); Keramitsoglou 2005; [Frid & Caswell 2017](https://academic.oup.com/book/26583)
67. [Kubat et al. 1998](https://link.springer.com/article/10.1023/A:1007452223027); [Solberg et al. 1999](https://ieeexplore.ieee.org/document/774704); Keramitsoglou 2005
68. [Zhang et al. 2019](https://www.sciencedirect.com/science/article/pii/B9780128050521000243)