Main Reference: Marine Pollution
1st edition
© 2013 Dr. Geert Potters
ISBN 978-87-403-0540-1
Available online: http://bookboon.com/en/marine-pollution-ebook

Second Reference: Marine pollution
5th Edition
Clark, R.B. (2002):
Oxford University Press
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1 What is Marine pollution?

Marine pollution as defined by the Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP), as part of the basic framework of the UN Convention on the Law of the Sea (UNCLOS) 1982 (Article 1.4), is:

"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 seawater, and reduction of amenities."

1.3 Classification of pollution forms (pollutants)

Pollutants can be classified in different ways.

- According to their physicochemical constitution.
  - **Inorganic compounds** (like the atmospheric pollutants; Nitric monoxide (NO), Nitrogen dioxide (NO₂), and SO₂ or like metal ions);
  - **Organic in nature** (like wastewater, the nitrogen and phosphorus-laden run-off of agricultural land or petroleum derivatives).
  - **Not chemical in origin** (sound, light).

- According to their physical state
  - **Solid form**, such as the plastic debris and sludge.
  - **Found in the atmosphere**, either as
    i. **drifting solids** (flying ashes, heavy metals adhering to dust particles and particulate matter),
    ii. or as **gases** (like volatile organic compounds).
  - **Solutes**: Rivers will carry a number of solutes (nitrogen fertilizers, agricultural run-off, remains of antibiotics, medication and hormones).
• According to their persistence in the environment.
  – **Biodegradable pollutants.** they will be mineralized by bacteria or otherwise assimilated in the metabolism of any of the organisms in the environment) and therefore will not continue to exist in the ecosystem for a long time, e.g. cooking waste, sewage and manure.
  – **Pollutants dissipate spontaneously (rapidly) and lose their damaging:**
    i. heat, discharged with the cooling water of a power station;
    ii. acids and bases, due to the buffering capacity and the large volume of the ocean in which they end up;
    iii. cyanides, produced in metallurgical industries, also dissociate and dilute quickly in seawater (with only the immediate neighborhood of the discharge feeling negative effects of the poison).
  – **Conservative or persistent pollutants.** They are not subject to bacterial attack and are not dissipated, but are reactive in various ways with plants and animals causing harmful effects. Examples are:
    i. Heavy metals (mercury, copper, lead, zinc and so on)
    ii. radioactive sources,
    iii. chlorofluorocarbons in the atmosphere, dioxins and pesticides.
    iv. apolar pollutants usually display a tendency to bioaccumulate, i.e. animals at higher trophic levels accumulate significantly higher levels of these chemical compounds.

• According to their source as point source or nonpoint source pollution.
  – **Point source pollution** can be traced back to a single, identifiable spot where the pollutant originated – for example, a sewage pipe from a company, the noise from a windmill or the leak of the oil drilling platform.
  – **Nonpoint source pollution** cannot be attributed to a specific location, and has a rather diffuse source. Examples comprise agricultural runoff, dust from strip mining, or urban storm water runoff. Nonpoint source pollution is the leading cause of water pollution in the United States today, with polluted agricultural runoff the most important form.
Table 1-1. Types, sources, and effects of marine pollution.

<table>
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<tr>
<th>Type</th>
<th>Primary Source</th>
<th>Effect</th>
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| Nutrients             | Runoff approximately 50% sewage, 50% from forestry, farming, and other land use. Also, airborne nitrogen oxides from power plants, cars, etc. | - Promote algal blooms in coastal waters.  
- Decomposing algae depletes water of oxygen, killing other marine life.  
- Can spur algal blooms (red tides), releasing toxins that can kill fish and poison people. |
| Sediments             | Erosion from mining, forestry, farming, and other land-use; coastal dredging and mining.          | - Cloud water; impede photosynthesis below surface waters; clog fish gills.  
- Smother and bury coastal ecosystems.  
- Carry toxins and excess nutrients. |
| Pathogens             | Sewage, livestock.                                                                                  | - Contaminate coastal swimming areas and seafood.  
- Cause cholera, typhoid and other diseases. |
| Alien Species         | Several thousand per day transported in ballast water; also spread through canals linking bodies of water and fishery enhancement projects. | - Out-compete native species and reduce biological diversity.  
- Introduce new marine diseases.  
- Associated with increased incidence of red tides and other algal blooms, a problem in major ports. |
| Persistent toxins     | Industrial discharge; waste-water discharge from cities; pesticides from farms, forests, home use, etc.; seepage from landfills. | - Poison or cause disease in coastal marine life, especially near major cities or industry.  
- Contaminate seafood.  
- Fat-soluble toxins that bio-accumulate in predators can cause disease and reproductive failure. |
| Oil                   | 46% from cars, heavy machinery, industry, and other land-based sources; 32% from oil tanker operations and other shipping; 13% from accidents at sea; remaining sources include offshore oil drilling and natural seepage. | - Low-level contamination can kill larvae and cause disease in marine life.  
- Oil slicks kill marine life, especially in coastal habitats.  
- Tar balls from coagulated oil litter beaches and coastal habitat.  
- Oil pollution is down 60% from 1981. |
| Plastics              | Fishing nets; cargo and cruise ships; beach litter; wastes from the plastics industry and landfills. | - Discarded fishing gear continues to catch fish.  
- Other plastic debris entangles marine life or is mistaken for food.  
- Plastics litter beaches and coasts and may persist for 200 to 400 years. |
| Radioactive substances| Discarded nuclear submarine and military waste; atmospheric fallout; industrial wastes.             | - Create “hot spots” of radioactivity.  
- Can enter food chain and cause disease in marine life.  
- Accumulate in top predators and shellfish, which are eaten by people. |
| Thermal               | Cooling water from power plants and industrial sites.                                              | - Kill off corals and other temperature sensitive sedentary species.  
- Displace other marine life. |
| Noise                 | Supertanker, other large vessels and machinery.                                                     | - Can be heard thousands of kilometres away under water.  
- May stress and disrupt marine life. |
1.4 Sources
Overall, the pollution that ends up in the seas and oceans, originates from four distinct sources. As represented in Figure 1-2, the major part of all pollution comes from the land, either through run-off and discharges (via waterways; 44%) or through the atmosphere (33%). Only 12% of all pollution is due to maritime activity and shipping accidents. Dumping of garbage and sewage, as well as the consequences of offshore drilling and mining make up for the rest (resp. 10% and 1%).

![Figure 1-2. Share of the different sources of pollution into the marine environment (After IMO 2012)](image)

1.4.1 Runoff from the land
The main transport of pollutants from the land to the sea occurs, evidently, through rivers (Figure 1-1 and Figure 1-3). Rivers take up different forms of waste material from the land, which ends up in the oceans. The most direct load of pollutants comes from the urban and industrial sewage systems that are dumped in the rivers.

Type of runoff
a. urban and industrial runoff
b. agricultural run-off
This urban and industrial runoff, together with agricultural run-off, contains high levels of nitrogen and phosphorus. As the levels of nitrogen and phosphorus rise (eutrophication), the so-called algal blooms: massive growth of the unicellular algae in the sea will occur. When they die, the remaining biomass is mineralize by bacteria, which thereby consume so much oxygen that the water beneath these blooms becomes anaerobic. Any fish or invertebrate life there is bound to die.

c. runoff from dust particles coming from metal mines, washing away in the rivers. These metals can then disturb the normal metabolism of plant and animal life.

1.4.2 Airborne (atmospheric) emissions from the land
The atmosphere is another way for pollutants to reach the ocean.
Types of atmospheric pollution which affects the marine environment include the following
1. Lighter dust fractions and debris will be taken up by the wind and blown towards the ocean. A great number of dust particles will carry metal traces, which are spread out by this way.
2. **The greenhouse gases**, which, by warming the earth, also **raise the temperatures in the oceans**. A secondary consequence seems to be that the increased concentration of CO$_2$ in the atmosphere contributes to **ocean acidification**.

3. **Combustion processes** (like car engines) produce a significant amount of SO$_2$ and NOx as well. These will increase the occurrence of acid rain.

![Figure 1-3. Inputs of pollution into the marine environment](image-url)

1.4.3 Shipping and accidental spills

**Shipping activity may pollute the atmosphere** in two major ways (Figure 1-7):

- **Ship’s engines as well as the incineration of garbage**: They produce CO$_2$, SO$_2$ and NOx, which will add to global warming and acid rain formation.

- **Cooling systems** may still be operating on freons and other chlorofluorocarbons, and occasionally some halon gases (*fire extinguishing agents* which are gaseous when discharged) are still at hand for fighting specific fires. Their accidental release and subsequent escape of these gases to the stratosphere furthers the build-up of chlorofluorocarbons (CFCs) in the ozone layer and the degradation of the latter.

**Shipping activity may pollute the ocean in different ways**

- **“grey water” (polluted sewage water)** As people live on ships, a certain quantity of “grey water” (polluted sewage water) is being produced by people, in the kitchen, the showers…. Part of that goes overboard, the oceans are able to deal with raw sewage through natural bacterial action.

- **bilge water**: A bilge is the lowest space of the ship. It is the area where two sides of the ship meet. At this space all water (bilge water) that does not drain off over the side of the deck is accumulated. This water may be from rough seas, rain, minor leaks in the hull, or interior spillage. Bilge water may contain water, oil,
urine, detergents, solvents, chemicals, particles, and other materials. The collected water must be pumped out to prevent the bilge from becoming too full and threatening to sink the ship. Cleaning out the bilge tank is therefore bound to release a quantity of pollutants.

**ballast water** To start with, when **ballast water** is taken up, it is bound to contain a number of microscopic life forms, such as algae and larval forms of invertebrates that belong to the specific region the ship resides in. When the ballast water is pumped out, possibly even after a few weeks, organisms may end up thousands of kilometres away from the region where they belong. This is called **biological contamination**.

![Figure 1-4](http://globallast.imo.org/)

**Figure 1-4.**

**Figure 1-5.** Ballast water – hitch-hiking invasive species. Source: http://globallast.imo.org/
Similarly, there are the organisms that attach themselves to the ship hull in a process called biofouling (Figure 1-6). Calcareous fouling organisms (protected by a calcium-enforced exoshell) include barnacles, bryozoans, molluscs, polychaetes and tube worms.

Examples of non-calcareous (soft) fouling organisms are seaweed, hydroids, algae and bacterial biofilms. Together, these organisms form fouling communities on all kinds of maritime objects.

Roughly 90% of the species that are transported unknowingly does not survive the transition to a new habitat. The remaining 10% is able to stay alive and happens to be seen now and then. They cause no harm whatsoever. 1% of the transported species, however, is able to establish a firm presence in its new home. These are called exotic species, or, with a more popular term, “aquatic hitch hikers”. About 10% of these
exotics even ends up threatening the normal ecological processes around them, chasing the local (endemic) organisms out of their habitat, taking over the region, spreading new diseases, etc… These species are called **invasive**. They are responsible for more than $120 billion in annual losses in the US alone.

![Figure 1-6. Biofouling on ship hull](image)

On the other hand, **prevention of biofouling** presents an environmental danger in itself, to be found in the layers of paint and antifouling agents covering all sides of the ship. Many of these chemical mixtures contain biocides – products that are designed to kill the different sea organisms that try to attach themselves to the hull, thereby favouring corrosion or decreasing the hydrodynamic character of the ship. Over time, these biocides will dissolve from the paint matrix they were originally applied in, and end up in the sea. Similarly, there is the zinc and aluminium coming from materials used to prevent other surface materials on hull of the ship from corroding. The zinc ions that dissolve end up in the water surrounding the hull.

![Figure 1-7. Imposax in dog whelks. The doc whelk (*Nucella lapillus*) is used as an ecological indicator in the North Sea. Their population is greatly diminished due to containing TBT containing ship coatings, causing an imbalance of in the sex hormones, which resulted in the female genitalia changing into their male counterparts, so that the females could no longer reproduce.](image)
Cargo lose Lastly, there is the possibility that ships sometimes lose part of their cargo, due to human error, storm wind and waves. Some estimate that over 10,000 containers are lost accidentally at sea every year.

Accident: Most of marine pollution is simply by accident.
The largest aquatic form of accidental pollution (Figure 1-7) caused by the maritime sector is oil spills. As crude oil consists of a wide range of different hydrocarbon molecules with different molecular weight and properties, it is not easy to give a concise view of the total damage that is done by an accidental spill. Apart from the highly visible heavy oil that covers the water, the animals and the shores, a large number of lighter components are present as well. These lighter components are likely to do even more damage in the long run, as they are stored in the adipose tissue of different animals in the food chain. Examples of these lighter components comprise the monocyclic and polycyclic aromatic hydrocarbons, which are difficult to clean up, and bound to cause cancer and other health problems after a few years of continuous exposure. We will discuss this in more detail in Chapter 4, Oil and organic pollution.

1.4.4 Ocean dumping
Dumping involves depositing all the waste materials from factories and industries, tankers and ships and sewerage waste materials into the oceans and seas. Radioactive waste is also dumped in the oceans and usually comes from the nuclear power process, medical use of radioisotopes, research use of radioisotopes and industrial uses. Ocean dumping can destroy entire habitats and ecosystems when excess sediment builds up and toxins are released.

Plastic dumping There are also large chunks of plastic that are being dumped along the coast, in rivers, etc.… Once they arrive in the ocean, they float along on the oceanic gyres which concentrates this kind of debris in the different oceans. This waste material is the main killer of life in the ocean and may take up to 450 years to be degraded.

1.4.5 Deep sea mining
A last source of pollution is deep sea mining. This process attempts to unearth the deposits of sulfides and important and precious metals (such as silver, manganese, copper, gold and zinc), which are often created near hydrothermal vents, at about 1400–3700 m below the ocean surface (Figure 1-8).
The mining occurs with hydraulic pumps and buckets being taken up and down to reach the ores and transport them to the surface.

Ecological consequences of deep sea mining:
A number of concerns have already been raised:

- Digging up parts of the sea floor disturbs the benthic ecosystems close to the hydrothermal vents. These ecosystems are often teeming with life, containing many species that are unique to the vents and with a high primary production. In addition, damage to those ecosystems may impact large regions of the benthic zone in the oceans.
- Mining these deposits may result in leakage of the toxic sulfides, altering the composition of the water column.
- Sediment plumes could have the greatest impact. Plumes are caused when the tailings (remains) from mining (usually fine particles) are dumped back into the ocean, creating a cloud of particles floating in the water.
Two types of plumes are distinguished: (1) seafloor plumes, which will affect the local turbidity and clog the feeding apparatus of the benthic organisms down below, and (2) surface plumes, which could affect light penetration in the water near the ocean surface, threatening primary production by the phytoplankton, and alter the chemical composition near the surface, affecting all planktonic life forms.

Figure 1-8. Hydrothermal circulation. This occurs when seawater penetrates into the ocean crust, becomes heated, reacts with the crustal rock, and rises to the seafloor. Seafloor hydrothermal systems have a major local impact on the chemistry of the ocean that can be measured in hydrothermal plumes. Some hydrothermal tracers (especially helium) can be mapped thousands of kilometres from their hydrothermal sources, and can be used to understand deep ocean circulation. Because hydrothermal circulation removes some compounds from seawater (e.g. Mg, SO$_4^{2-}$) and adds many others (He, Mn, Fe, H$_2$, CO$_2$), it is an important process in governing the composition of seawater. (Source: http://www.pmel.noaa.gov/vents/chemistry/information.html)