CHAPTER 16 BOX 3

RADIOACTIVE WASTES IN THE MARINE ENVIRONMENT

During the nuclear testing era from 1945 to about 1990, the oceans were contaminated with many radionuclides. They were introduced in fallout from atmospheric nuclear bomb tests, liquid waste discharges from nuclear facilities, and deliberate dumping of solid and liquid radioactive wastes at ocean dump sites. Some of these radionuclides from these sources do not occur naturally on Earth.

Once in the marine environment, radionuclides become involved in biogeochemical cycles and behave in the same way as the stable isotopes of their elements (if stable forms exist). Thus, each radioisotope has its own distinct behavior in the oceans according to which element it is an isotope of. For example, tritium (hydrogen-3), a radioactive form of hydrogen released in nuclear explosions, quickly combines with oxygen to form water. The radioactive water molecules then join the hydrologic cycle and ocean circulation system, where they behave almost indistinguishably from other water molecules. An iodine radioisotope, iodine-131, enters solution in ocean water and is concentrated by marine biota, particularly certain species of algae. Plutonium does not occur naturally but is rapidly attached to particles when it enters the ocean environment. Most plutonium is carried with these particles to the sediment, where it remains until it has decayed to other elements.

Concentrations of radioisotopes are easily measured, even at exceedingly small concentrations, and sometimes even in an environmental sample that contains only a few atoms of the isotope. For this reason, radioactive isotopes have proven invaluable as tracers to study geochemical, biological, and physical processes in the oceans (**Chap. 8**). They are also commonly used as tracers in biological systems, including human medical scans. However, radioactivity can also have adverse effects on marine ecosystems and on human health. The primary concern is that some anthropogenic radioisotopes are concentrated in seafood and that people who eat the seafood will have an increased risk of cancer.

With the exception of very limited areas surrounding a few former nuclear bomb testing sites, the concentrations of anthropogenic radioisotopes in seafood are well below background levels of naturally occurring radioactive elements. Nevertheless, the prevalent, although not universally accepted, theory of carcinogenicity is that any increase in radioisotope intake will increase the risk of cancer. The assimilative capacity of the oceans for anthropogenic radioactive materials may therefore be considered essentially zero. In reality, a very small increase in radioactivity above natural background levels will not produce a measurable or significant increase in cancers. Hence, the oceans do have an assimilative capacity for radioactive materials, but it is small and not easily defined, because there is no generally accepted level of incremental risk.

Because the ocean's assimilative capacity for radioactive materials is so small, international agreements require that the release of such materials to the oceans be eliminated entirely. Almost all nations adhere to these agreements. The United Kingdom does continue to have a leak of some liquid radioactive wastes from its nuclear industrial complex at Sellafield, but the amount of radioactivity now released in discharges is very small, the radioactive materials release is apparently now largely contained within soil at the site, and the area is continuously monitored. In addition, after the fall of the Soviet Union, it was revealed that the Soviet Union had routinely dumped and discharged very large quantities of solid and liquid radioactive wastes directly into the Arctic Ocean and the Sea of Japan (Fig. 16B3-1), and into rivers that empty into the Arctic Ocean. This ocean dumping continued until 2005, when Russia finally agreed to a global treaty that bans such practices.

The quantities of radioactive wastes dumped in the oceans by the former Soviet Union far exceeded the total amounts dumped by all other nations (**Fig. 16B3-1b**). The material dumped by the former Soviet Union material includes a number of nuclear submarine reactors still containing their nuclear fuel (**Fig. 16B3-1a**). These fuel rods contain very large amounts of potentially dangerous radionuclides, including strontium-90 and cesium-137, which could bioaccumulate and threaten human health if released to solution and dispersed. At present, very little radioactive material appears to have been released from sunken submarines and solid wastes. However, there is still some concern that these wastes, and radioactive wastes dumped on land and into rivers, may eventually be released to contaminate seafood, especially in the Arctic Ocean and the Greenland and Bering Seas, which are among the world's most important fisheries. Fortunately, it is known that many elements for which radioactive isotopes are used in, or produced by, nuclear power plants are strongly absorbed by particles, so the probability of any release and transport of significant quantities of radioactive material from sediments at dumpsites is very low.

The massive earthquake and huge tsunami that damaged the Fukushima Daiichi nuclear power reactors in Japan in 2011 led to a sequence of events that caused large quantities of water containing radioactive elements to be released into the oceans. The total amount released to the oceans was only about one quarter of the amount released to the environment by the Chernobyl, Ukraine nuclear power disaster in 1986 (**Fig. 16B3-1c**), but considerably larger than the total estimated amount of radioactive waste dumped in the oceans prior to 2005. Despite the large quantities of radioactivity discharged to the oceans at Fukushima, studies showed that radioactivity levels in the environment were rapidly reduced with distance from the plant site and within five years were too low for any adverse effects to be found in any marine organisms studied, ranging from microalgae to mollusks and fishes even in ocean areas close to the accident site. The only major impact on the oceans appears to have been precautionary fishery closures of a substantial area of the oceans around Fukushima.

Fears of radioactivity releases fueled by media accounts of the Fukushima and Chernobyl, Ukraine (1986), power plant accidents, and a 1979 accident at Three Mile Island in Pennsylvania (that released small amounts of radioactivity to the atmosphere) have caused public perception to conclude that nuclear power plants are unsafe and nuclear power should not be used in the future. While these fears are understandable, they are not based

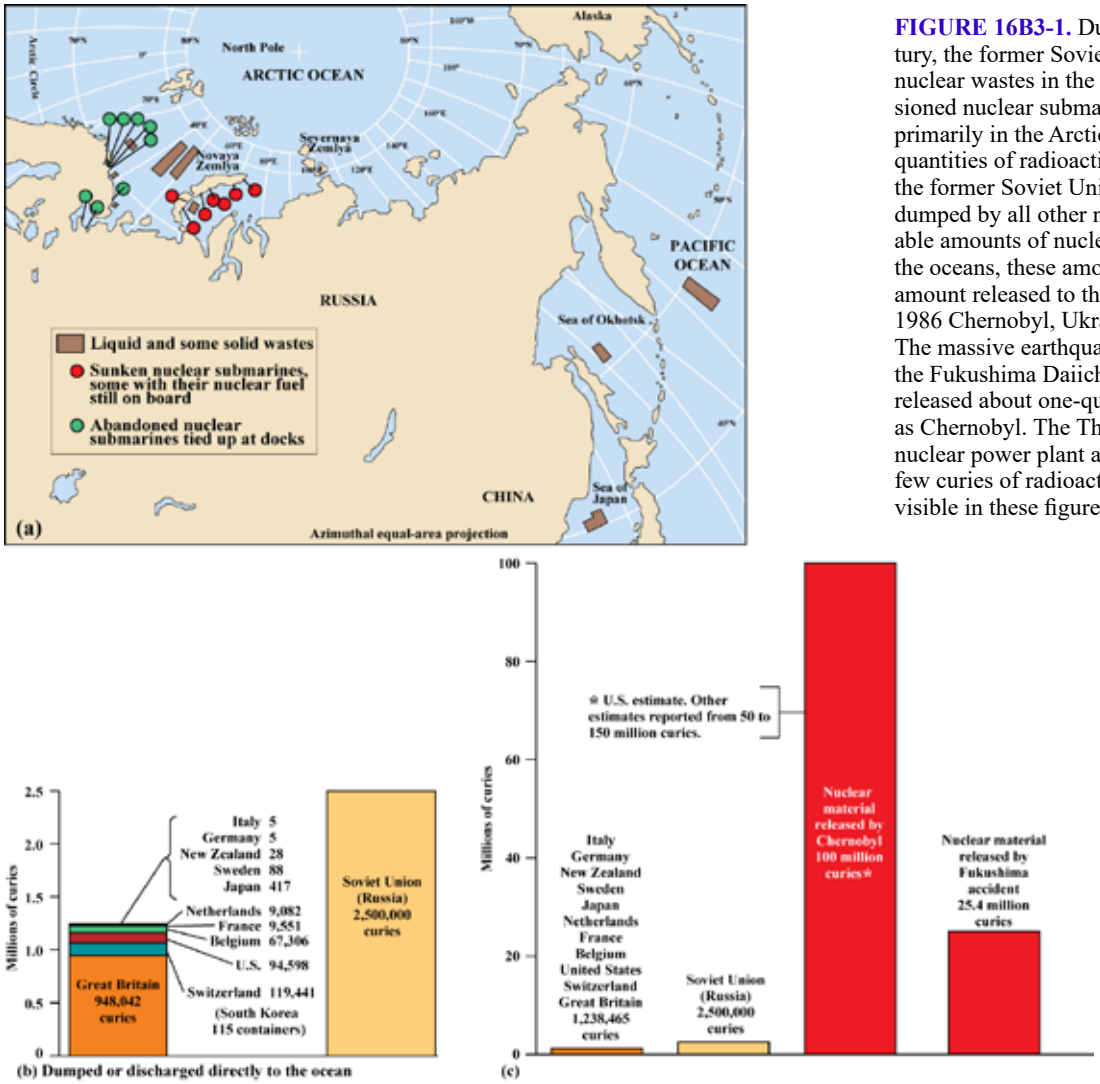

FIGURE 16B3-1. During the latter half of the 20th century, the former Soviet Union dumped large quantities of nuclear wastes in the oceans. (a) Damaged or decommissioned nuclear submarines were dumped and abandoned primarily in the Arctic and Pacific Oceans. (b) The quantities of radioactive wastes dumped in the oceans by the former Soviet Union far exceeded the total amounts dumped by all other nations. (c) Even though considerable amounts of nuclear wastes have been dumped in the oceans, these amounts are small compared to the amount released to the environment as a result of the 1986 Chernobyl, Ukraine, nuclear power plant accident. The massive earthquake and huge tsunami that damaged the Fukushima Daiichi, Japan nuclear plant in 2011, released about one-quarter as much radioactive material as Chernobyl. The Three Mile Island, Pennsylvania, nuclear power plant accident in 1979 released only a few curies of radioactivity, an amount far too small to be visible in these figures.

on scientific facts. At present, there are about 4280 nuclear power plants operating worldwide, and these provide about 9.11% of the world's electrical power generation capacity and needs. Among all the technologically available sources of electrical power, nuclear power is the only technology that is free from carbon dioxide emissions to the atmosphere, can operate 24 h per day and can be operated at variable levels to meet hourly demand fluctuations, and that can provide city scale amounts of power from a single plants with a small land-use footprint (i.e., does not require large areas of agricultural or natural landscape to be altered). Other than the Chernobyl accident that occurred at a poorly designed reactor with no safety containment vessel, and the Fukushima accident that happened as a response to one of the most powerful earthquakes, plus one of the largest tsunamis ever experienced in human history, no other major accidents have occurred that have caused deaths or significant radioactivity exposure beyond a small number of plant employees. Nuclear power's generation is a mature technology that can be ramped up rapidly worldwide using reactors that have benefited from decades of safety improvements both in design and site location, many scientists believe it deserves further consideration as it offers one of the only readily available technology that can reduce carbon dioxide emissions rapidly and, thus, enable humans to reduce the risk of incurring climate change consequences that could extend to planet-wide mass extinctions.

Waste disposal is a significant issue faced by the nuclear power industry. However, this can be addressed by means such as the use of breeder reactors that reduce the radioactivity of waste from other nuclear power plants or by safe storage and disposal of the wastes in a location where they will remain in place, undisturbed, for long enough for radioactivity to decay to background levels. The best such geologically stable long-term storage locations are likely to be beneath the sediments in the center of oceanic tectonic plates. It is not well known that technologies to emplace radioactive waste deep within ocean sediments were extensively researched and developed in the U.S. in the 1970s and 1980s. However, this research was abandoned after the London Dumping Convention adopted a ban on all disposal of radioactive wastes in the oceans. This ban, established in 1993 despite substantial scientific disagreement, effectively removed two-thirds of the Earth's surface from any consideration as a suitable site for geological storage of radioactive wastes.

REFERENCES

Figure 16B3-1a – Data from Yablovkov, Y., and Coauthors, 1993: *Facts and Problems Related to Radioactive Waste Disposal in Seas Adjacent to the Territory of the Russian Federation*. Office of the President of the Russian Federation, 72 pp.

Figure 16B3-1b – Data from Broad, W.J., 1993: Russians Describe Extensive Dumping Of Nuclear Waste. The New York Times, accessed 31 March 2026, https://www.nytimes.com/1993/04/27/science/russians-describe-extensive-dumping-

of-nuclear-waste.html.
– Data from IAEA, 1999: Inventory of radioactive waste disposals at sea. Accessed 31 March 2026, https://www-pub.iaea.org/MTCD/Publications/PDF/te_1105_prn.pdf.

Figure 16B3-1c – Data from Steinhauser, G., A. Brandl, and T.E. Johnson, 2014: Comparison of the Chernobyl and Fukushima nuclear accidents: a review of the environmental impacts. *Sci. Total Environ.*, **470–471**, 800–817, https://doi.org/10.1016/j.scitotenv.2013.10.029.