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News & Highlights

Fukushima Water Release Stirs Controversy

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In late August 2023, China cut off seafood imports from Japan [1] and criticized its neighbor for being "extremely selfish and irresponsible" [2]. In Seoul, the Republic of Korea, protesters marched through the streets, held a candlelight vigil, and attempted to force their way into the Japanese embassy [3]. The environmental organization Greenpeace denounced Japan for violating human rights and breaking international law [4].

What sparked these angry reactions was Japan's first release of contaminated water from the disabled Fukushima Daiichi Nuclear Power Station into the Pacific Ocean. Since a tsunami knocked out the cooling systems of four of the station's reactors in 2011, about 1.3×10^6 m^3 of radioactive water has accumulated at the site and is being stored in metal tanks [5]. On August 24, 2023, Tokyo Electric Power Company Holdings, Inc. (TEPCO), the utility that owns the facility, began discharging some of this backlog [6].

The water had gone through a purification process that removes or dilutes most of the radioactive nuclides, a process that has received approval from the International Atomic Energy Agency (IAEA), the United Nations body that sets international radiation safety standards [7]. Many scientists say they are confident the water poses no threat to humans or ocean life. "The doses are extremely low—much, much lower than what we get from a dental X-ray or from background radiation or in the food we eat," said Jim Smith, professor of environmental science at the University of Portsmouth in the United Kingdom. "Would I eat fish from the Pacific? Certainly," said Georg Steinhauser, professor of applied radiochemistry at the Vienna University of Technology in Austria. "There is no possible scenario in which the environment or a human consumer might suffer from unacceptable doses." However, a few scientists have spoken out against the company's plan, and opposition to the release continues.

The problematic water at Fukushima comes from three sources: groundwater that has been seeping into the facility, precipitation that falls on the damaged buildings, and water that TEPCO sprays on the still-hot cores of the reactors to cool them [7,8]. Because this water flows over and through contaminated parts of the site, it becomes very radioactive as well. TEPCO collects the water and sends it to filtration plants, which remove mostly strontium and cesium isotopes, and then through a reverse osmosis system that reduces the concentration of residual salts [7]. Some of this partially treated water is reused for cooling the cores [7]. However, some of the radioactivity remains [7]. In 2013 the company added another treatment stage, the advanced liquid processing system (ALPS), that uses ion exchange to lower the concentrations of 62 potentially harmful radionuclides [9,10].

TEPCO has also taken several steps to slow the buildup of radioactive water at Fukushima. For example, the company has installed a so-called ice wall, a series of coolant-filled tubes 30 m below the surface that rings the facility [11]. When groundwater moving through the soil reaches the wall, it freezes instead of entering the site. These measures have cut the rate of wastewater accumulation from 540 m^3 per day to 90 m^3 per day [7]. Still, more than 1000 tanks of ALPS-treated water now sprawl across the plant's grounds (Fig. 1) [7]. About 35% of these tanks hold water that is ready to be released. The rest of the tanks contain water that was processed shortly after the filtering system went online and that was not purified to the same standard [8]. This water will have to go through ALPS a second time before it can be discharged [8].

TEPCO says that the tanks have become obstacles to decommissioning the power station [12]. The company's plan is to send the stored water through a pipeline beneath the seabed that extends 1 km from the shore [13]. Emptying all the tanks will take 30 to 40 years. After evaluating TEPCO's procedures and safeguards, the IAEA in July of 2023 issued a report that concluded "the approach and activities to the discharge of ALPS treated water taken by Japan are consistent with relevant international safety standards" [7]. In August 2023, the initial 7800 m^3 of water began flowing into the ocean.

The water will contain small amounts of what Nigel Marks, associate professor of electrical engineering, computing, and mathematical sciences at Curtin University in Perth, Australia, called "radioactive nasties," isotopes such as cesium-137, cesium-134, strontium-90, and iodine-129. But TEPCO's data suggest that when ALPS works properly, it can reduce the concentrations of these isotopes to levels that are below regulatory limits. For example, the company's monitoring shows that over the last seven years, concentrations of the cesium and strontium radionuclides in ALPS-treated water almost always fell below these limits [14]. The dose of radiation someone might get from the ALPS-treated water "is irrelevant" compared to other everyday exposures, Marks said.

But ALPS cannot remove tritium, a weakly radioactive isotope that can cause harm at very high concentrations because it damages the DNA of organisms that eat or drink it [15]. The levels of

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Fig. 1. An aerial view of the Fukushima nuclear power station shows many of the more than 1000 storage tanks at the site that hold radioactive water. Most of the tanks contain water that has been through the ALPS purification process at least once, which removes 62 radionuclides. However, 24 tanks hold water that has only been through preliminary filtering to remove cesium, strontium, and residual salts. Credit: Japan Ministry of Land, Infrastructure, Transport and Tourism (CC0).

tritium in the ALPS-purified water average around 569 000 Bq·L^{-1} and can reach more than 1×10^6 Bq·L^{-1} in individual tanks [16,17]. For comparison, the World Health Organization's drinking water standard is 10 000 Bq·L^{-1} [18]. TEPCO's solution to this problem is to mix the water produced by ALPS with seawater until the tritium concentration is no more than 1500 Bq·L^{-1} [9]. In total, the plant will release 22 TBq of tritium per year [18].

Discharging the water is safer than holding it in tanks that could be damaged in a future earthquake, said Steinhauser. "The Pacific Ocean, with its enormous volume, is the best possible reservoir to dilute this water." Tritium-containing water from the 1979 Three Mile Island nuclear accident in the United States was boiled until it evaporated—a process that took two years [19]. Some experts suggested doing the same at Fukushima [20]. That option would have been just as safe because the tritium would have rapidly dissipated in the atmosphere, said Marks, but discharging the water into the ocean allows more control over the process.

To put the radiation releases into perspective, Smith, Marks, and a colleague compared them to data from other nuclear sites in a report published in the journal *Science* in October 2023 [18]. Sellafield, a facility in the United Kingdom that processes and stores nuclear waste, releases over 1000 times more strontium-90 and cesium-137 per year, for instance [18]. The La Hague nuclear fuel reprocessing plant in France discharges about 450 times more tritium [18]. The scientists noted that studies conducted near these and other nuclear sites found that the radiation exposure for humans was low and did not detect serious effects on wildlife. The authors also pointed out that the amount of radioactivity in the ocean from naturally occurring potassium-40, about 7.4×10^6 PBq, dwarfs the amount that will come from Fukushima [18].

Some of the strong reaction to the Fukushima plan reflects tension between Japan and its neighbors [21], and some likely stems from mistrust of TEPCO, which has a "history of wavering transparency," as one writer put it [22]. But Smith said that the continued opposition to the release in the face of scientific evidence is exasperating. "The idea that this poses a risk to the Pacific islands or to China—I am struggling to find words."

Still, a few scientists have questioned the safety and wisdom of the release. One of their concerns is the possibility of bioaccumulation, in which toxic or radioactive compounds present in small amounts in the environment can build up to high levels in organisms' tissues as they concentrate through movement up food chains [23]. Some of the radionuclides in the ALPS-treated water, such as ruthenium-106, cobalt-60, and strontium-90, can bioaccumulate, and they can also concentrate in seafloor sediments [17]. Although TEPCO ran lab experiments to measure effects of the ALPS-treated water on certain marine organisms, "it did not properly design or perform scientifically valid studies on bioaccumulation, or on key sublethal, cellular-level effects on DNA, RNA, and signaling proteins," said Robert Richmond, research professor and director of the Kewalo Marine Laboratory at the University of Hawaii, Manoa, HI, USA. One of the most vociferous critics of the release, Richmond also rejects the argument that discharging the Fukushima water is acceptable because other nuclear facilities release more radiation. The ocean is already polluted with plastics, toxicants, and radiation, he said. "This is an opportunity to improve how things like this are handled when future disasters occur, and not add additional stressors to marine ecosystems already compromised by the ocean dumping of undesirable wastes."

In any case, Japan plans to continue the releases. The IAEA is checking for radiation, sending fish from the ocean near Fukushima to independent labs for testing [24]. If the results of these and other monitoring efforts show that radiation levels remain low, they could help quell some of the concerns about the process, said Steinhauser. "I hope the situation will calm down very soon."

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