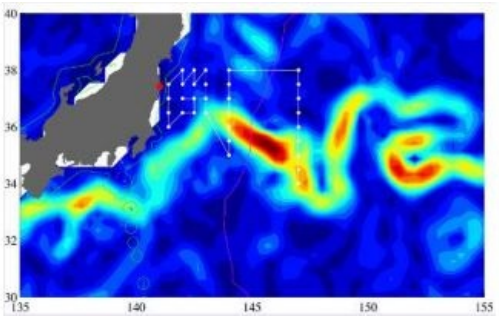
Sampling the Pacific for Signs of Fukushima



An international research team from Woods Hole Oceanographic Institute, USA, is reporting the results of a research cruise it organised to study the amount, spread and impacts of radiation released into the ocean from the tsunami-crippled reactors in Fukushima, Japan. The group of 17 researchers and technicians from eight institutions spent 15 days at sea in June 2011 studying ocean currents and sampling water and marine organisms up to the edge of the exclusion zone around the reactors.

Led by Ken Buesseler, a senior scientist and marine chemist at the Woods Hole Oceanographic Institution (WHOI), the team found that the concentration of several key radioactive substances, or radionuclides, were elevated but varied widely across the study area, reflecting the complex nature of the marine environment. In addition, although levels of radioactivity in marine life sampled during the cruise were well below levels of concern for humans and the organisms themselves, the researchers leave open the question of whether radioactive materials are accumulating on the seafloor sediments and, if so, whether these might pose a long-term threat to the marine ecosystem. The results appear in the 2 April 2012 online edition of the journal *Proceedings of the National Academy of Sciences* (PNAS).

On 11 March 2011, a magnitude 9.0 earthquake caused a tsunami that devastated the northeast coast of Japan and severely damaged the Fukushima Dai-ichi Nuclear Power Plant. In the weeks following, emergency crews poured tonnes of water directly onto the reactors to keep them cool and prevent them from going critical. Much of the contaminated water washed directly into the Northwest Pacific or collected in the basement of the reactor buildings and seeped slowly out, carrying with it a number of different radionuclides. In addition, several explosions in the reactor buildings sent additional radioactive materials into the atmosphere, much of which eventually landed in the ocean.

Among the materials released were caesium-134 and -137, two radioactive isotopes that do not occur naturally in the ocean. Caesium-134 has a half-life (the time it takes for one half of a given amount of radionuclide to decay) of a little over two years, and so could come only from the reactors at Fukushima. Caesium-137 has a half-life of roughly 30 years and is known to have entered the Pacific as a result of aboveground nuclear weapons tests in the 1950s and 60s, providing a benchmark against which to measure any additional releases from the reactors.

Buesseler, who began his scientific career studying the transport and mixing of artificial radionuclides in the ocean from sources such as weapons testing and the 1986 explosion at Chernobyl, recognised the importance of organising an oceanographic research mission soon after events at Fukushima began to unfold. With primary support from the Gordon and Betty Moore Foundation and additional support from the National Science Foundation, he brought together an international group that included physical oceanographers Steven Jayne and Irina Rypina, also from WHOI, and marine biologist Nicholas Fisher from the State University of New York (SUNY) Stony Brook.

The group departed Yokohama, Japan, on 6 June 2011 aboard the University of Hawaii research vessel *Ka'imikai-o-Kanaloa* and sailed a saw-tooth pattern that began 600 kilometres (350 miles) offshore and came as close as 30 kilometres (18 miles) from the damaged power plant. Along the way, the group conducted extensive water sampling from the surface to as deep as 1,000 metres (3,200 feet) and made more than 100 net tows to collect samples of phytoplankton, zooplankton, and small fish. They also released two dozen drifters, instruments that move with ocean currents and report their position via satellite back to shore.

In addition to their own samples, the group also collected water that they later shipped to labs at seven other institutions. Together, the ongoing effort is examining 15 different radionuclides likely to have been released from Fukushima. Their initial results, detailed in the PNAS paper indicate that the combined amount of radioactive material from the damaged power plant constitutes the largest accidental release of radiation to the ocean in history.

Despite this, analysis of samples from the study site show that the amount of radiation in the ocean fell well below EPA standards that would deem it unsafe to use as drinking water.

In addition, they found that concentrations of caesium isotopes varied widely from station to station. Data from the drifters helped shed more light on this. First, the region is dominated by the Kuroshio, a large, fast current much like the Gulf Stream that flows north near the coast of Japan before turning east along the shore of the Chiba Peninsula. At the same time, a smaller, nutrient-rich current known as the Oyashio flows south along the northeast coast and mixes with the Kuroshio offshore from Fukushima.

As if to underscore that complexity, the group found that the Kuroshio acted as a barrier that prevented the movement of radionuclides to the south. In addition, they found the highest levels of radiation not in samples taken within sight of the reactors, but in those taken much further south along the coast of Ibaraki. The drifter tracks later revealed that an eddy, a swirling mass of water that sometimes breaks off from strong currents like the Kuroshio, had formed in the area and hugged the coast, likely drawing in contaminated water and maintaining higher concentrations of radionuclides.

As a result, radiation levels in the eddy were as much as 1,000 times higher than those before the start of the accident, but these remained well below levels of concern for humans and marine organisms and were approximately one-sixth the level of radiation that marine organisms receive from naturally occurring radionuclides such as potassium-40.

Samples of plankton and small fish confirmed this. Levels of caesium isotopes and another, faster-decaying isotope of silver found in the organisms collected during the cruise ranged from below detection level to levels that, while elevated, remained within standards set for human consumption.

Another open question is why radiation levels in the waters around Fukushima have not decreased since the Japanese stopped emergency cooling operations. According to Buesseler, it may be an indication that the ground surrounding the reactors has become saturated with contaminated water that is slowly seeping out in to the ocean. It may also be a sign that radionuclides in ocean sediments have become remobilised.

This imaged map shows the sampling stations and cruise track near the Kuroshio Current (shown in yellow and red). Sampling began 400 miles offshore and passed within 20 miles of the nuclear complex. (Steven Jayne, Woods Hole Oceanographic Institution).

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