≡		SCIENTIFIC AMERICAN™					SUBSCRIBE						
	S	U	s	т	A	I	N	A	в	I	I		
Crippled Fukushim	a React th	ors Ai e Acci	re Stil ident	ll a Da	anger	, 5 Ye	ars af	ter					
Japan's citizens, and scientis	sts worldwide	e, do not l	have ans	wers to ba	asic healt	h and ei	nvironme	nt					

questions

By Madhusree Mukerjee on March 8, 2016 Véalo en español



thierry ehrmann/Flickr, CC BY 2.0

A D V E R T I S E M E N T

On March 11, 2011, a giant tsunami from the Pacific Ocean swept over the 10-meter sea wall surrounding six reactors at the Fukushima power plant on Japan's east coast. The crashing water <u>caused reactor cores to overheat</u> and melt, and subsequent hydrogen explosions damaged three reactor buildings. Radiation spewed in every direction. The country shut down all of its more than 40 reactors, and <u>investigations began into radiation</u> <u>exposure</u> to tens of thousands of nearby residents, as well as to <u>wildlife on land and sea</u>. But major questions still loom today, in part because the damaged reactors are too dangerous to enter, and in part because the plant's operator, the Tokyo Electric Power Company (Tepco), is reluctant to share information.

In the midst of this maelstrom, Japan in February started up a third reactor among those that had been shut down. But even as the government seeks to leave the disaster behind, Fukushima remains a wound that will not heal—for former residents, the local landscape and for the Japanese psyche. Two thirds of the perplace dreads are ther assident enough.



and for the Japanese psyche. 1 wo-thirds of the populace dreads another accident enough to oppose the restarts. More than 1,100 square kilometers of villages, mountains and forests remain uninhabitable, and future generations will still be cleaning up the plant site, according to Japan's Ministry of Economy, Trade and Industry (METI). Echoing citizens' groups, some scientists are complaining that important questions about the disaster's impact are not being addressed. Authorities, they suspect, are subtly discouraging certain kinds of scientific research, possibly because they fear findings that could further alarm the public. In some ways they want this to go away and say things are back to normal, observes marine radiochemist Ken Buesseler of Woods Hole Oceanographic Institution.

Exacerbating widespread suspicions of a cover-up, this February Tepco admitted it had waited for two months after the accident before announcing the meltdowns—which possibly delayed evacuations and endangered lives. The uranium fuel in three of the six reactors eventually melted, and explosions blew holes in the roofs of three reactor buildings, releasing radioactive iodine, cesium and other fission products over land and sea. Emergency managers on site, desperately trying to cool the molten cores, poured water into the damaged reactor buildings using fire-hoses. As a result, highly contaminated water flowed directly into the Pacific Ocean.

Since then, Tepco has substantially cleaned up the site. It has capped shredded roofs, removed spent fuel from a damaged reactor and constructed ice walls to stanch the flow of groundwater that was washing contaminants from the site into the ocean. Because the molten fuel still generates heat by radioactive decay, however, Tepco has to keep pumping water through the reactor buildings and collecting as much as possible—some 400 cubic meters a day, stored in on-site tanks. Around 8,000 workers are now assisting in the cleanup.



NATURALFLOW/FLICKR, CC BY-SA 2.0

Not all is going well, however. Engineers still have to locate the molten fuel, which seems to have melted through steel vessels. It remains so radioactive that no humans can enter the reactor buildings. Tepco has "no idea where and how much fuel debris is in the reactor now," says nuclear engineer Tadahiro Katsuta of Meiji University. Last April, Tepco <u>sent a</u> robot into one of the buildings to photograph the damage, with mixed results, and it also intends to use robots to find and remove the globs of molten uranium, steel and other substances by 2021. According to METI, fully cleaning the site will require half a century, when most of the dangerous radionuclides will have decayed. Where the lethal debris will



end up is unclear, however, because Japan has no permanent repository for nuclear waste.

The 1,000 or so tanks of contaminated water, which leak from time to time, pose another headache. Tepco is removing the most <u>abundant contaminant, cesium</u>, from the cooling water before it is sent to the storage tanks, but the water retains high concentrations of radioactive strontium and tritium. This February, the company reported a spike in strontium levels at the plant site—likely indicating a tank leak. So the company is painstakingly cleaning the stored water of all radionuclides except tritium, which is difficult to separate out. Because tritium concentrations remain many times higher than the drinking water level prescribed by the World Health Organization, however, fishery cooperatives are not allowing its release into the ocean. (Tepco did not respond to Scientific American's questions about the tank contents, or anything else.)

Solid waste is piling up as well. Cleaning streets, houses and playgrounds within the evacuated zone, which stretches some 50 kilometers northwest of the plant site, has generated millions of bags of contaminated topsoil and debris, which also await a final resting place. Almost 800 bags got carried off by typhoon Etau last year, however, and were deposited miles away, says Hajime Matsukubo of the Citizen's Nuclear Information Center in Tokyo. Hundreds were never found.

Meanwhile, after five years, some 100,000 people are still waiting to return to their homes. Last year the Japanese government announced that it will eventually lift evacuation orders for regions where a person would receive an annual radiation dose of 20 millisieverts or less. That figure, several times higher than what the International Commission on Radiological Protection recommends for safety, poses an "unacceptable" risk, Matsukubo says. (According to a report from the U.S. National Academy of Sciences, a dose of 20 millisieverts increases the chances of mortality from cancer by roughly one in 1,000, and residents would be receiving comparable doses year after year.) No matter: a year after this zone is opened up, Tepco will stop providing compensation to its 32,000 former residents. Exile may be permanent, however, for tens of thousands of people from the most contaminated areas.



CESIUM (CS) AND STRONTIUM (SR) LEVELS IN SEAWATER JUST OFF THE FUKUSHIMA PLANT SITE HAVE FALLEN STEEPLY SINCE THE ACCIDENT, BUT TWO YEARS LATER REMAINED WELL ABOVE PRE-ACCIDENT LEVELS. *THIS FIGURE IS REPRODUCED FROM SLIDE #2 IN MICHIO AOYAMA'S PRESENTATION AT IAEA SCIENTIFIC FORUM 17-18*



SEPTEMBER 2013 VIENNA, AUSTRIA (HTTP://WWW-PUB.IAEA.ORG/MTCD/MEETINGS/PDFPLUS/2013/CN207/PRESENTATIONS/1028-AOYAMA.PDF) WITH PERMISSION OF AOYAMA.

Accidents, ailments and trauma caused by the evacuation has led to 3,200 deaths, including many suicides, according to the *World Nuclear Industry Status Report*, 2015. The number of <u>cancer cases is hotly disputed</u>. A 2013 study published in *Energy and Environmental Science* estimated roughly 1,000 future cancer deaths from radioactive cesium, too few to be distinguished from those caused by other factors. Last year, however, an ultrasound screening program of around 300,000 children who had been living in the affected area revealed a startling 110 thyroid cancers—a 30-fold increase from the norm, allegedly caused by radioactive iodine.

Radiation epidemiologist Yoshisada Shibata of Nagasaki University dismisses as "nonsense" the claim that the disaster is responsible for those cases, however. Unlike in Chernobyl, he explains, no Fukushima children who were infants at the time of the disaster have tumors. Moreover, many of the growths are surprisingly big. "It's too fast," he says. "If these cancers started after the accident, it's not possible that they should grow so large." The highly sensitive screening method employed, he and others contend, has detected growths that would never have become problematic enough to be diagnosed by a doctor—so its results cannot be gauged against those from other surveys, they say.

Other studies indicate that the disaster has adversely affected many other creatures—in particular those living in the forests, which have not been cleaned. In a count of 57 species of birds in 400 locations of varying radioactivity, ecologists Anders Møller of the National Center for Scientific Research in Orsay, France, and Timothy Mousseau of the University of South Carolina documented sharp reductions in abundance and diversity in the areas of higher contamination. The team's ongoing studies in Chernobyl, which has a similar biotope, may indicate why: many birds have "cataracts in the eyes, smaller brain size, tumors, reduced fertility, especially in the males," says Mousseau—all of which decrease their ability to survive.

In another study, conducted in less contaminated areas, a Japanese team found physiological and genetic damage in an ubiquitous species of butterfly, the pale grass blue. Other researchers have documented defects in the growth of almost all fir trees in highly contaminated areas, abnormalities in aphids near the power plant and the activation of a DNA-repair mechanism in rice plants in response to radiation. Despite such scattered findings, however, no comprehensive evaluation exists of how the terrestrial ecosystem is faring under the radioactive onslaught.

Remarkably, research on Fukushima's impact on the marine ecosystem is even more scarce—even though the disaster represented the single largest pulse of radioactivity ever injected into an ocean. In 2011, Nicholas Fisher of the University of Stonybrook found widespread cesium contamination of zooplankton and small fish up to 600 kilometers off the Japanese coast, and in 2011 another study documented the absence of rock shell snails in a 30-kilometer stretch of coastline near Fukushima. But little else is known about the accident's impact on marine organisms

T





THE DAMAGED FUKUSHIMA DAIICHI NUCLEAR POWER STATION AS SEEN DURING A SEA-WATER SAMPLING BOAT JOURNEY, 7 NOVEMBER 2013. IAEA MARINE MONITORING EXPERTS WERE SENT TO JAPAN TO OBSERVE SEA WATER SAMPLING AND DATA ANALYSIS. IAEA IMAGEBANK/FLICKR, CC BY-SA 2.0

Although the cesium concentration has now fallen below regulatory limits because of dilution in the Pacific, its level in the ocean many kilometers off Fukushima remains well above pre-accident levels. One reason is that rain and rivers keep washing the radionuclide off the land and into the sea. In addition, roughly a hundredth of the blast of radiocesium released in 2011 seems to have been absorbed into clays on the seafloor. "It's going to stay put near Japan," Buesseler says. As a consequence, levels of cesium also remain elevated in fish such as greenlings, which feed off the sediments close to the Fukushima plant site.

Another concern is radioactive strontium. Scientists say levels in seawater near the plant are not declining, possibly because of recurrent leaks from the on-site tanks. "You could actually see in the ocean when one of these tanks would leak—you'd get a big spike in Strontium-90," Buesseler notes. Whereas cesium behaves in organisms rather like potassium, being absorbed and excreted fairly quickly, strontium is chemically similar to calcium and accumulates in bones. Although consumers of Fukushima's fish may be safe, because they tend not to eat fish-bones, the radionuclide could become a long-term concern for a few of the fish themselves. Mathew P. Johansen of the Australian Nuclear Science and Technology Organization and others estimate that, for the first three years at least, certain species such as greenlings living very close to the plant received such high doses from cesium and strontium that reduced reproduction and subtle genetic changes were possible. Johansen calls for investigations into the ecological web built upon the now contaminated sediments off Fukushima.

Indeed, unanswered questions abound. "You want to know why some fish have higher contamination than others, how quickly they will recover, what's coming down the rivers, how much is on the seafloor, how quickly that is buried—those are the type of oceanography and radioecology questions that are really not being well addressed," Buesseler says. One reason is the scarcity of funds for such research, argues Mousseau. The Japanese government seems to be cutting off funds for monitoring radionuclides in water alongside Fukushima, Buesseler says. Shibata finds such concerns "biased," pointing out that several ministries offer funds for environmental research. But another Japanese scientist, who asked not to be named, claimed that whereas grants are readily available for researchers whose projects are unlikely to discover significant impacts from the disaster, they are exceedingly scarce for others.



Other muddiness remains. Several Japanese researchers who aided Mousseau's team asked not to be credited in its published papers, fearing adverse impacts on their careers. Buesseler reports a similar experience. "There's this kind of self-censorship going on," Mousseau says.

With more than 400 nuclear power plants operating around the world, many of them on coastlines and in countries with far weaker safety standards than Japan's, another such calamity is not inconceivable. Knowing more about its impacts could help save lives and livelihoods. Unfortunately, Buesseler notes, "We're missing opportunities to learn from this accident."

Rights & Permissions

)



Α

Madhusree Mukerjee

0

Madhusree Mukerjee is a freelance writer and former editor at *Scientific American*.

Recent Articles

4

Α

5 Years Later, the Fukushima Nuclear Disaster Site Continues to Spill Waste

The Impending Dam Disaster in the Himalayas

Apocalypse Soon: Has Civilization Passed the Environmental Point of No Return?

4 Years after Fukushima						
1	Is Radioactive Hydrogen in Drinking Water a Cancer Threat?					
2	The Nuclear Odyssey of Naoto Kan, Japan's Prime Minister during Fukushima					
2	Government Urged to "Step In" to Halt Fukushima Plant Leaks					
	Japan's Offshore Wind Power Rises within Sight of Fukushima Nuclear Plant					



Every Issue. Every Year. 1845 - Present S U С R В Ε В S Ν 0 W W U S 0 0 L You Tube f 5 Store About Press Room More Scientific American is part of Springer Nature, which owns or has commercial relations with thousands of scientific publications (many $of them \, can be found at www.springernature.com/us). \ Scientific American maintains a strict policy of editorial independence in the second structure of the second struct$ reporting developments in science to our readers.

© 2016 SCIENTIFIC AMERICAN, A DIVISION

