Federal Ministry
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Climate Action, Environment,
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Fukushima – Not Even a Worst-Case Event

Fukushima, March 2011 – A three-fold disaster: earthquake, tsunami, nuclear accidents. Three reactor cores melt down, 164,000 people have to be evacuated, losing their homes and possessions. Still, Japan was lucky. It could have been much worse.

On 11 March 2011, the east coast of Japan's main island Honshu was hit by a brutal earthquake. A vast 14-meter-high wall of water rolled inland. Anything merely damaged by the earthquake was destroyed by the ensuing tsunami. The nuclear power plant Fukushima Daiichi (number one) was hit hard. The electricity supply to the reactor complex broke down, and the backup power generators gave out. The engineered diversion of an underground river was destroyed; the entire site was inundated from two sides at once, from the ocean and from the land. The cooling systems stopped working; the cores in Units 1, 2 and 3 began to melt. Furthermore, hydrogen explosions caused serious damage to the reactor buildings of Units 1, 3 and 4.[1] Large amounts of radioactivity were released into the environment. On the disaster‘s tenth anniversary, the German public TV news-program *Die Tagesschau* featured the following headline: “Beben, Tsunami, Super-GAU: Die Katastrophe von Fukushima“ (Earthquake, Tsunami, Super-GAU: The Fukushima Disaster).[2]

The German Duden dictionary defines *Super-GAU* as a “particularly devastating maximum credible accident“. It took a group of independent American scientists only until 2014 to reach a very different conclusion after an extensive investigation into the reactor disaster: “What is clear is that, in terms of the amount of radiation released, the Fukushima Daiichi

[1] The explosion in Unit 4 is presumed to have been triggered by hydrogen in a vent stack shared with Unit 3 and did not originate in Unit 4 directly.
[2] *Die Tagesschau*, 'Beben, Tsunami, Super-GAU: Die Katastrophe von Fukushima', 11. March 2021, see https://www.tagesschau.de/multimedia/bilder/10-jahre-fukushima-113.html, or also *Die Wiener Zeitung*, 'Zehn Jahre nach dem Super-GAU: Fukushima will grün sein' (Ten years after the meltdown: Fukushima wants to be green), see https://www.wienerzeitung.at/nachrichten/politik/welt/2095723-Zehn-Jahre-nach-dem-Super-GAU-Fukushima-will-gruen-sein.html, both accessed on 3 April 2021.

accident was far from a worst-case event".[3] In other words, it could have been much worse.

Estimates indicated that less than 10 percent of the radioactive iodine and caesium inventories of the three molten reactor cores were released into the environment. Over the following weeks, the biggest danger arose from the spent fuel stored in the cooling pools inside the reactor buildings. These swimming-pool-like structures are located between the fourth and fifth floor of the reactor buildings. The hydrogen explosions had literally blown away the roofs of the affected blocks 1, 3 and 4. The pools were out in the open.

The biggest problem: Reactor 4 was not operating when the earthquake hit; its core had been unloaded and was located in the spent fuel pool. Reactor operator TEPCO affirmed that the water level in the pool had dropped, initially by 1.5 metres, one sixth of its depth, presumably due to a "spill over" during the earthquake. The temperature then rose, and a few days later enough water would have evaporated to fully expose the fuel elements. Overheating would have lead to the self-ignition and ultimately to the destruction of the fuel, releasing a large amount of radioactivity – under the open sky. At times, experts from the US Nuclear Regulatory Commission feared the pool had already dried out and a fire was unavoidable.

Five days after the disaster had struck, the US authorities recommended expanding the evacuation zone from 20 km to 80 km. They urged US citizens in Japan who did not want to or could not leave the country to at least relocate to outside the recommended evacuation radius.

Frantic activities began in a bid to get water into the spent fuel pool in Unit 4, initially using helicopters, then with concrete pumps equipped with telescopic arms that were able to reach all the way to the fifth floor (see photograph). No one was able to assess the situation properly. The highly contaminated premises of the power plant made any attempt by disaster relief workers to enter the accident zone a suicide mission.

The TEPCO management played with the idea of completely vacating the premises and leaving the site entirely to its own devices. The prime minister at the time, Naoto Kan, prohibited this but asked Shunsuke Kondo, then head of the Japan Atomic Energy

[3] D. Lochbaum, E. Lyman, S.Q. Stranahan, 'Fukushima – The Story of a Nuclear Disaster', The New Press,

Commission, for advice. Kan's question: which areas would have to be evacuated “if everything that could go wrong did go wrong“? On 25 March 2011, Kondo provided his confidential answer: if the spent fuel pool in Unit 4 dried out and a fire ensued, then more than four fifths of the radioactive inventory would be released. All inhabitants living in a radius of 170 km would have to be forcibly evacuated and voluntary evacuation to a distance of 250 km—including metropolitan Tokyo—would have to be made possible.[4] This would require the relocation of 50 million people, 40 percent of the Japanese population. Inconceivable.

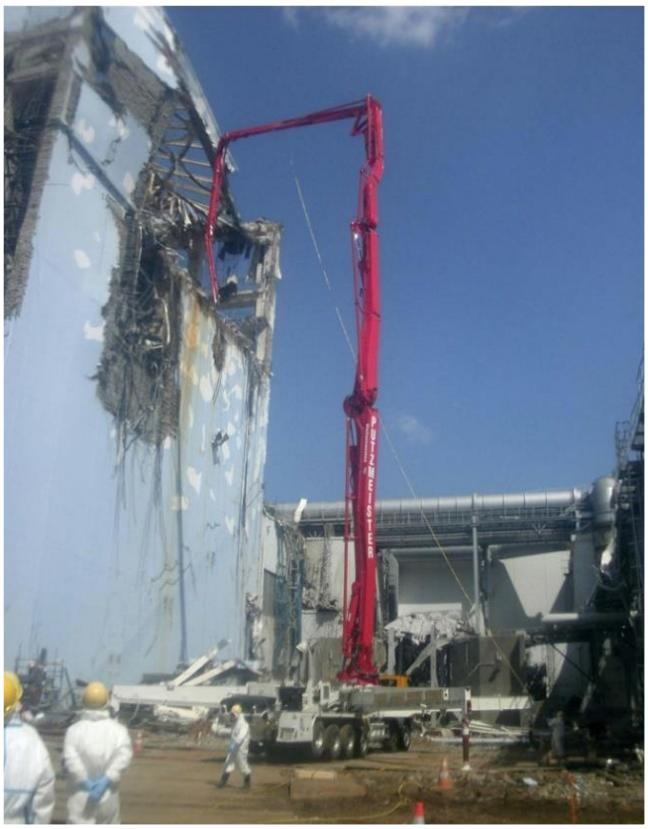


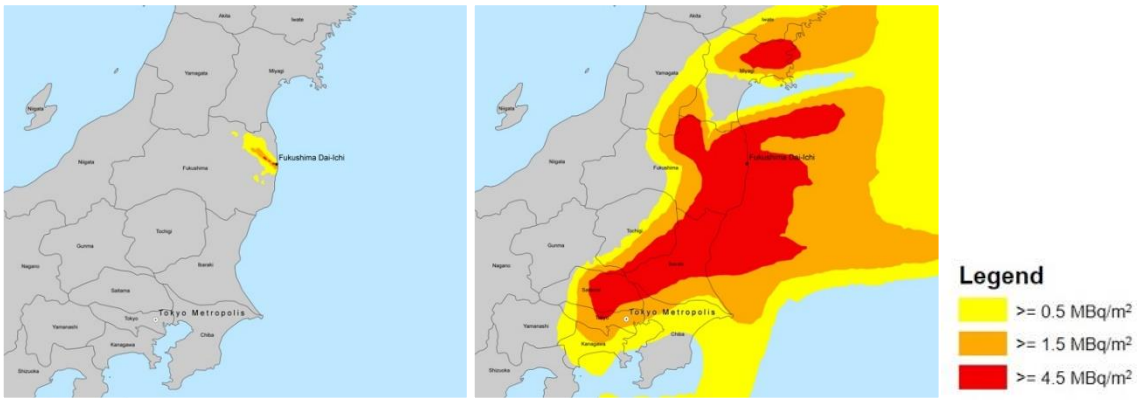
Figure 1: A concrete pump injects water into the spent fuel pool of the severely damaged Unit 4 of the Fukushima Daiichi nuclear power plant. (Photograph: TEPCO)

Five years later, researchers at Princeton University in the US carried out a computer simulation of the spread of radioactivity under the weather conditions prevailing at the time and in the event of a spent fuel fire in the cooling pool of Unit 4. The outcome: depending on the weather conditions, up to 29 million people would have had to leave their homes due to the same radioactivity levels that led to the evacuation of 164,000 people in March 2011.

[4] Naoto Kan, „My Nuclear Nightmare“, Cornell University Press, 2017.

Notwithstanding the tragedy and immense human suffering locally, humanity has been fortunate in Fukushima Daiichi under the circumstances. Thanks to a lucky break, sufficient cooling water was provided for the spent fuel pool in Unit 4. Around 600 cubic metres of water from the reactor well inadvertently found their way to the spent fuel pool.

Figure 1: The spread of contamination in the event of a fire in the spent fuel pool of Fukushima Daiichi-4 under real weather conditions on 19 March 2011.



Real contamination in March 2011 and contamination in the event of a fire in Unit 4.[5]

The highly radioactive fuel was successfully unloaded from the spent fuel pool in subsequent years. The molten cores of reactors 1, 2 and 3 have likewise been successfully cooled (ongoing to this day). However, over ten years after disaster struck, the spent fuel assemblies of Units 1 and 2 are still stored in their respective spent fuel pools while those in Unit 3 have only partially been unloaded. Dozens of cubic metres of water need to be injected daily to cool the molten reactor cores, and large amounts of inert gas still need to be provided to prevent hydrogen explosions. The disaster continues to unfold.

Former prime minister Naoto Kan has gained clear new insights: “We now have sun, water and wind – there is no longer any need to rely on nuclear power“, he told the international press on the occasion of the 10th anniversary. Former prime minister Junichiro Koizumi, who belongs to the opposite political camp, sat next to him. And nodded.

[5] Figure Michael Schöppner, in Frank N. von Hippel, Jungmin Kang and Masafumi Takubo, “Plutonium: How Nuclear Power’s Dream Fuel Became a Nightmare“, Springer, 2019. With permission.