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Ten Years of Fukushima Disinformation

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March 11, 2021, marked the tenth anniversary of the 2011 Tōhoku earthquake, which, together with the tsunami it triggered, devastated the northeast coast of Japan's main island of Honshu and triggered the Fukushima nuclear accident.

However, it is Fukushima that has remained in public awareness. The event's memory is shaped mainly by unsubstantiated horror stories that have decisively influenced nuclear power debates. This article examines widespread myths about the events and contrasts them with the facts.

Consequences of the Tōhoku Earthquake and Tsunami

The earthquake was the largest to hit Japan and the fourth largest worldwide in recorded history. It and the subsequent tsunami cost between 15,000 and 20,000 lives.

Abandoned emergency shelter for evacuated families. Photo by Amardeo Sarma.

The consequences, however, went far beyond the deaths. Half a million people fled (Choate 2011; McLaughlin 2016), and 300,000 people lost everything (The Hiroshima Syndrome 2014). Nearly 230,000 were still living as disaster refugees in 2015 (Shim 2015). In 2017, there were reportedly over 130,000 evacuees (Internal Displacement Monitoring Centre 2017), and in 2018 there were still nearly 60,000, including over 5,600 in emergency shelters (Hyakutake and Miyazaki 2018). In 2019, there were still 48,000 displaced persons (“The State of Recovery…” 2020). Add to that the mental health consequences: post-traumatic stress disorder (Wolters Kluwer Health 2017; Harada et al. 2015), increased suicide rates (Orui et al. 2018; Takebayashi et al. 2020), and stigmatization of Fukushima evacuees (Marcantuoni 2018; Karz et al. 2014).

Ten years later, the consequences of this disaster remain. In Japan, the nuclear accident is remembered merely as one—albeit particularly deplorable—aspect of the Tōhoku earthquake. In many parts of the world, Fukushima was taken as an occasion for an anti-nuclear mobilization push. Alongside Three Mile Island in 1979 and Chernobyl in 1986, Fukushima became the third world catastrophe of nuclear power.

In Germany and elsewhere, anti-nuclear activists successfully labeled the Tōhoku disaster as the “Fukushima disaster,” conflating the earthquake and tsunami devastations with the consequences of the nuclear accident. The latter dominated the headlines this year while mainly ignoring the tsunami victims’ fate and displaced persons. Many still erroneously believe that those who fell victim to the earthquake and tsunami were victims of a nuclear disaster.

The anniversary of the Tōhoku earthquake disaster has become Fukushima Memorial Day in Germany. Narratives about “Fukushima cancers,” “uninhabitable regions,” and “radioactive water” disposal into the sea have amplified this perception, but the facts offer a different perspective.

The Facts about What Happened in Fukushima

In the early afternoon of March 11, the tsunami hit the Fukushima Daiichi nuclear power plant (Fukushima 1) in Ōkuma in Fukushima Prefecture. The utility Tokyo Electric Power Company (TEPCO) operated six boiling water reactor units that had gone online between 1971 and 1979.

Three of the six reactors were in operation at the time of the earthquake. They were automatically shut down after the earthquake hit by shooting the control rods into the reactor cores. Their residual heat removal systems started up as intended. Diesel-powered emergency generators had to take over the power supply to the units.

The subsequent tsunami wave flooded switchgear equipment, emergency diesel generators, and batteries housed in the Fukushima Daiichi basement. The flooding resulted in a complete loss of onsite power. As a consequence, both the residual heat removal systems and the instrumentation and control systems were unavailable. Crews had to operate in total darkness and received hardly any information about the plant's status. There were no elaborate emergency plans or emergency drills for such an eventuality; the staff had to improvise. Operators, power plant management, and emergency staff were not prepared for three beyond-design-basis accidents of this magnitude. Communication and transport routes were destroyed, and the supply of fuel reserves, evacuation equipment, emergency power and pump units, and food for the personnel was delayed (Eidgenössisches Nuklearsicherheitsinspektorat [ENSI] 2018).

In units 1, 2 and 3, the reactors' residual decay heat could no longer be removed, which led to a core meltdown there. Besides, hydrogen gas was produced in the reactor systems due to the hydrolysis of coolant on the overheated zirconium cladding of the fuel elements, which escaped through leaks in the condensation chambers and the primary containments and accumulated in the upper floors of the reactor buildings. The hydrogen formed an explosive mixture with atmospheric oxygen, leading to hydrogen explosions in units 1 and 3 on March 12 and March 14. In the early morning of March 15, a hydrogen explosion also occurred in unit 4, which was not affected by the core meltdown because hydrogen gas was transported to this unit via common ventilation systems. It was not until the evening of March 15, more than four days after the accident began, that the cooling of the reactors could be stabilized. One week after the start of the accident, the external power supply was restored. The three damaged reactors achieved their "cold shutdown" status in December 2011 (ENSI 2011; Gesellschaft für Reaktorsicherheit [GRS] 2011).

Myths Surrounding Casualties and Their Causes

The molten fuel mass in units 1 to 3 of the Fukushima Daiichi nuclear power plant dripped in whole or in part from the damaged reactor pressure vessels onto the floor of the primary containment. There, it ate into the concrete structures and solidified. Thus most of the reactor inventory was held inside the containments, but leakage could no longer be prevented due to the earthquake and explosion damage and the late initiation of pressure relief. Controlled but unfiltered ventings also released large quantities of volatile radionuclides.

The full release of iodine-131, caesium-137, and cesium-134 is estimated at 3.7×10^{17} becquerels (Bq) of iodine equivalent, about one-tenth of the release in the Chernobyl accident. Nevertheless, like Chernobyl, Fukushima was classified at Level 7 (release $>5 \times 10^{16}$ Bq) on the International Nuclear and Radiological Event Scale (INES). Unlike with Chernobyl, no one at the power plant died from radiation over-exposure. As of October 2011, a total of 388 people received radiation doses above the 20 millisieverts (mSv) permitted annually for occupationally exposed persons. Fourteen people received more than 100 mSv. To date, there is one case of fatal lung cancer that has been officially recognized as an occupational disease, but it is implausible to have resulted from the accident itself (GRS 2016).

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) estimated that the expected number of premature deaths from cancer among nuclear workers would be so small as to be statistically insignificant. No casualties were expected among the civilian population that was evacuated in time (United Nations Scientific Committee on the Effects of Atomic Radiation 2014).

The nuclear accident itself did not cause any direct radiation-related deaths. Instead, the fatalities at and close to the nuclear power plant's site are due to the earthquake and tsunami and the evacuation measures taken after the nuclear accident.

Facts about the Indirect Consequences of the Fukushima Accident

The evacuations claimed between 1,000 and 1,600 lives. The official website of Fukushima Prefecture lists 2,238 disaster-related deaths (as of June 2018) (Fukushima Revitalization Station 2019) where not all were evacuated because of radiation. The newspaper *Tokyo Shimbun* (Japan for Sustainability 2016) counted 1,368 deaths due to evacuations in July 2016. Many older people died due to evacuation. Others committed suicide due to their not coming to terms with their dislocation.

Were the evacuations necessary to protect the population from high radiation exposure? Scientific studies paint a sober picture. The editorial of a whole series of studies concludes that the radiation's health consequences may have been significantly overestimated (Thomas and May 2017).

These studies are based on the controversial LNT (linear no-threshold), a mathematical risk model that has been used since the 1920s to predict the effects of radiation. It establishes a linear relationship between radiation dose and the development of cancer in tissue. There is no threshold value in this model, so it assumes that even the smallest quantity of radiation can cause cancer. It should be briefly mentioned that this model is used in practice as a precautionary measure because of the uncertainty involved. The idea is to prevent conceivable, though not proven, damages caused by radiation even at low doses.

Jeanne Goldberg criticized the model in her article "The Spectral to the Spectrum: Radiation in the Crosshairs" in this magazine (Goldberg 2018). Beyond that, misusing the model to predict possible deaths based on hundreds of millions of people receiving minimal radiation exposure is scientifically untenable.

The editorial in the series of studies mentioned earlier summarizes the findings of the paper on relocation measures:

> Based on the Judgement- or J-value method, between 5 and 10 times too many people were moved away from the Chernobyl area between 1986 and 1990, and the authors find it difficult to justify moving anyone away from Fukushima Daiichi on grounds of radiological protection. (Waddington et al. 2017)

The misjudgment of the consequences of the nuclear accident, both in terms of evacuations and the decision to phase out nuclear energy, has been demonstrably damaging. It is important to note that the Japanese authorities could not have decided otherwise in March 2011: after all, it is precisely the characteristic of an acute crisis that decisions have to be made under uncertainty, lack of information, and pressure to act (Brinks et al. 2017).

The authorities were bound by legal requirements and strict limits for evacuations; they had to act quickly because of the power plant's containment venting. At the time of the evacuation, it was unclear whether the power plant's situation would deteriorate. Radioactive releases could have become more extensive and weather conditions less favorable. But the subsequent decision to reopen large parts of the affected areas, based on careful assessment without time pressure, was justified.

The Myths of Death, Cancer, and Contamination through Fukushima

After the accident, a publication by Mark Z. Jacobson, a renewable energy researcher and staunch opponent of nuclear power, caused a stir. He claimed that there were about 130 (between fifteen and 1,100) cancer-related deaths and 180 (between twenty-four and 1,800) cancer-related illnesses due to Fukushima (Hoeve and Jacobson 2012). His paper is also based on the controversial LNT model. Even the smallest increases in radiation dose in remote regions of the world, such as the west coast of the United States, were included in the calculations.

But even those numbers pale compared to deaths from just about all other uses of technology by humans. Mark Lynas calls the publication "junk science":

> In this deeply flawed paper, he succeeds only in illustrating some of the absurdities in current radiological protection models, and that one thing we know for sure—even if those absurdities are ignored—is that the evacuation killed more people than the accident. (Lynas 2012)

The World Health Organization concurred:

> Outside the geographical areas most affected by radiation, even in locations within Fukushima prefecture, the predicted risks remain low, and no observable increases in cancer above natural variation in baseline rates are anticipated. (World Health Organization 2013)

Thyroid Cancer among Children

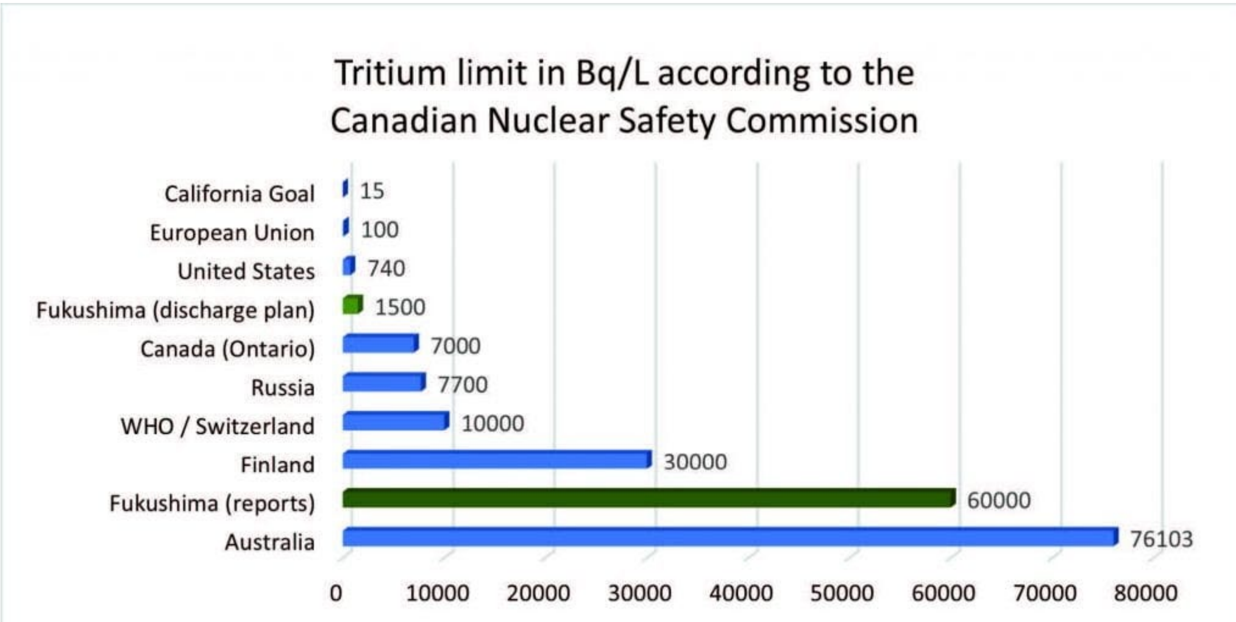
Thyroid cancer is the only form of cancer that has a proven link to nuclear reactor accidents. Human thyroid glands take up the volatile radioiodine formed during nuclear fission and released during a meltdown. This particular problem is more significant in iodine-deficient areas. The half-life of iodine-131 is only eight days; the dose rate is high because of this. To avoid radioiodine uptake, affected persons must take potassium iodide tablets early and avoid contaminated dairy products. In the first days of the accident, a lot depends on functioning medical care, health education, and food substitution. After the Chernobyl accident, where these three conditions were barely met, over 1,000 children developed thyroid cancer from the increased radiation.

Fukushima also reported an increased incidence of thyroid cancer in children after the reactor accident. An evaluation of various reports related to the much lower radiation exposure at Fukushima from international organizations concluded that it was difficult to link thyroid cancer to radiation exposure (Yamashita et al. 2018). Children had been overtreated, it said. According to this publication, distorted risk perception becomes a social problem, generates fear, and leads to psychological and mental consequences for those affected.

Fukushima Water

Reports about "contaminated" (implying contaminated with radioactive tritium) water in the tanks of the ruins of the Fukushima Daiichi power plant keep coming in. The water is stored in many tanks whose capacities are gradually running out. Experts recommended discharging it into the sea.

The concerns of residents and fishers are well-founded. If their fish are considered "contaminated," their income is at stake. This contamination is mainly caused by radioactive tritium, a hydrogen isotope. Tritium is not toxic; it is a beta radiation emitter with a half-life of 12.32 years, a weak emitter with low radiation levels. The storage water is the end-product of a complex filtering and evaporating procedure that removes most radionuclides from the reactor coolant and decontamination water. As a hydrogen isotope in water molecules, tritium cannot be removed by this process.



Graphics by Amardeo Sarma from data by the Canadian Nuclear Safety Commission (2009). The graph above relates the tritium concentration to biological effects and limits.

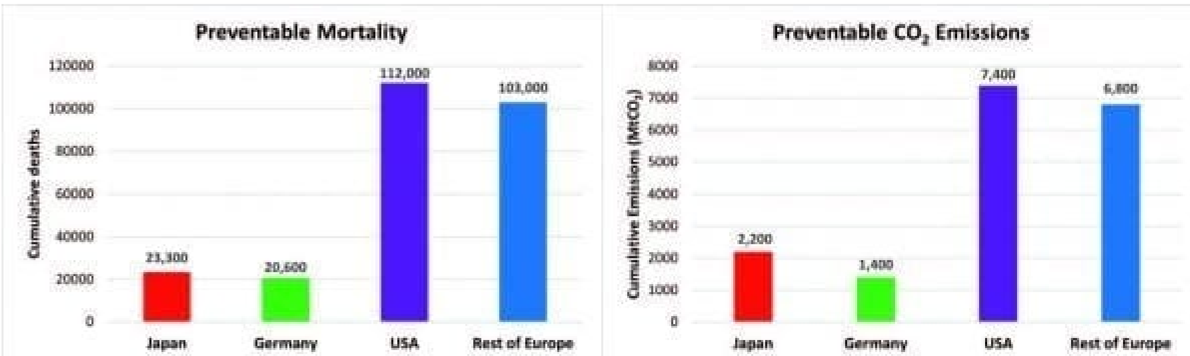
Reports in Germany claimed that 770,000 tons of “radiating liquid” were planned to be discharged into the sea (Dambeck 2017). As a reality check, we only need to compare the 60,000 becquerels of tritium per liter of Fukushima water mentioned with the WHO guideline of 10,000 becquerels for drinking water.

The same graph shows that water with the Fukushima concentration of tritium reported in the media could be offered as drinking water in Australia (Canadian Nuclear Safety Commission 2009). Current plans foresee a dilution with sea water to at most 1,500 Bq/L before disposal, down to well below WHO levels (TEPCO 2020). In the ocean, the water would be diluted to a few Bq/L and thus pose no danger to fish or the ecosystem (Brown 2018).

A Canadian publication also criticized the repeated demands to lower the limits for tritium because the current limits are more than sufficient (Dingwall et al. 2011). Reductions give a false impression that the current limits do not offer any safety. If they are then increased to more reasonable values by the authorities, as was the case after the reactor accident, this understandably arouses mistrust among some observers.

However, there may be a conflict of interest here. One of the authors of the Canadian publication has ties to Bruce Power, an energy company operating CANDU deuterium uranium reactors that have relatively large tritium emissions compared to light water reactors.

Germany: Consequences of Nuclear Phaseout



In March 2011, the German anti-nuclear mobilization caused an abrupt turnaround in the Christian Democrate Party-Liberal Party coalition's energy policy. The party had previously decided to extend German nuclear power plants' lifetime, which the anti-nuclear movement saw as a severe defeat, but the party backed down from that previous decision. The government shifted completely away from terming nuclear energy as a climate-friendly "bridge technology" until renewable energy systems could take over, which used to be the favorite argument of Chancellor Angela Merkel, a physicist.

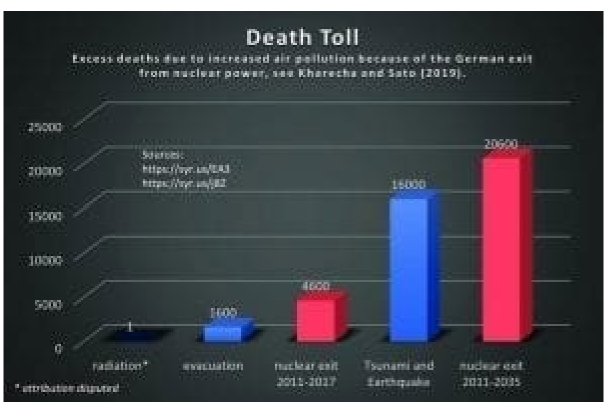
Merkel was genuinely shocked by the Japanese nuclear accident because now, unlike in Soviet Chernobyl, it had hit a Western capitalist high-tech society. Without reliable information on the accident's root causes, Merkel and her cabinet wrongly concluded that a similar accident could occur in German plants, and within three days they decided to phase out of nuclear power. Eight older German nuclear power plant units had their operating licenses immediately revoked. The remaining more modern plants were given a grace period of about a decade. In June 2011, the nuclear phaseout was approved by a broad cross-party majority in the Bundestag. An "ethics commission" made up of scientists, industrialists, NGOs, trade unions, and church representatives appointed by the Chancellor's Office—but including no experts in nuclear technology—provided catch-up legitimacy for this decision. To a large extent, all these decisions were made long before valid information was available about the Fukushima accident's causes. At no stage did the concerned check whether the conditions in Fukushima applied to German nuclear power plants.

The decision to phase out was never investigated in an evidence-based manner. The German reactor safety commission (RSK) stated that Fukushima could not be applied to German nuclear power plants, but the commission was ignored (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety 2020). German nuclear power plants are equipped with two redundant emergency power systems, hydrogen recombinators, and filtered containment venting systems. Vital systems and switchgear equipment are situated in flood-proof rooms. German nuclear power plant design considers the maximum 10,000-year flood event, whereas TEPCO considered only the maximum 100-year event. A German nuclear power plant at Fukushima's shoreside most probably would have withstood the tsunami thanks to its robustness (Die Bundeskanzlerin N.d.; Ethik-Kommission Sichere Energieversorgung 2011).

What were the consequences of Germany's phaseout of nuclear energy? Pushker A. Kharecha and Makiko Sato (2019a; 2019b) show the results using hypothetical scenarios. They found that Japan and Germany could have prevented about 28,000 premature deaths between 2011 and 2017 if they had phased out coal instead of nuclear power. These consequences were avoidable.

Thus, the shutdown of German nuclear power plants since 2011 resulted in about 300 deaths per year from particulate matter for every 1.5 GW of nuclear power lost, because nuclear power plants cannot be replaced entirely by renewable energy. The incredibly high number of over 100,000 deaths for the United States and the rest of Europe reflect the potential consequences if the involved countries would adopt a German-style nuclear phaseout linearly between 2018 and 2035.

Getting Serious about Climate Change



With severe consequences looming due to climate change, as Mark Lynas has shown in the timely new edition of his book *Six Degrees—Our Final Warning*, it is imperative that we use all available means for mitigation and adaptation (Lynas 2020). Mitigation requires us to come to a serious review of all low-carbon energy sources, including nuclear power, carbon capture and storage (CCS), bioenergy with carbon capture and storage (BECCS), in addition to renewable energy that itself is more than just wind and solar. All forms of energy generation come with their benefits and side effects. There is no free lunch.

The choices among the energy sources calls for a fact- and reality-based evaluation of all low-carbon energy benefits and side effects, neither exaggerating nor downplaying either based on political or tribal preferences. While clearly understanding the threat of global warming, the Biden administration appears more open to solutions outside the 100 percent renewable camp. It would be good to see the United States in the driver's seat again, this time not bound by old dogmas. Keeping working and safe nuclear power plants running and investing in all low-carbon energy technologies will be critical.

It should be kept in mind that the IPCC Special Report on the impacts of global warming of 1.5 (deg) C above pre-industrial levels includes all low-cabon energy sources, including nuclear energy in all its four scenarios. It is deplorable to see many climate activists completely ignoring the IPCC when its summary of the world's research does not suit their partisan solutions.

Conclusion

We classify the Fukushima accident as a serious industrial accident. However, the actual consequences pale against the background of the more severe destruction and casualty figures of the natural disaster. Fukushima was not the global catastrophe it is often made out to be. Tōhoku was one of the most severe national disasters in recent history for Japan. Measures must do more good than harm in this regard. The data strongly suggest that measures in Germany (and, in retrospect, Japan) were not appropriate. Governments worldwide should carefully analyze the Japanese accident to learn how their nuclear power plants can be better prepared for future accidents and learn from Japan's experience. It is imperative to weigh the negative consequences of phasing out versus the benefits of keeping each nuclear power plant. Governments and public authorities are well-advised to make their decisions based on science and facts rather than following popular narratives.

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