

INGSA CASE STUDIES

FUKUSHIMA - THE TRIPLE DISASTER AND ITS TRIPLE LESSONS:

*What can be learned about regulation, planning, and communication
in an unfolding emergency?*

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FUKUSHIMA DAIICHI NUCLEAR POWER PLANT, MARCH 2011

FUKUSHIMA - THE TRIPLE DISASTER AND ITS TRIPLE LESSONS

What can be learned about regulation, planning, and communication in an unfolding emergency?

On 11 March, 2011 a magnitude 9.0 earthquake struck off the North-eastern coast of the Japanese main island of Honshu. Although reactors at the Fukushima Daiichi Nuclear Power Plant shut down as expected, the 15m tsunami which followed caused a loss of power which disrupted the cooling systems. Over the next few days, four of the six reactors experienced catastrophic events, requiring the evacuation of plant personnel and residents of nearby villages in a 20km radius. Nuclear contamination has continued to hinder clean-up and reconstruction efforts in Fukushima prefecture, one of the three worst hit by the tsunami, and it is estimated that the plant itself could take up to 40 years to decommission. Moreover, subsequent investigations have revealed serious systemic issues in the regulation of nuclear power and in the mechanisms for provision of scientific advice to the public, policymakers, and to disaster response personnel, which has contributed to a considerable loss of public trust in both scientists and the Japanese government. Handling of the 'triple disaster', therefore, raises important questions for understanding the scale and extent of nuclear contamination after accidental release, but also about the need for realistic emergency planning and for consistency, accuracy and trust in the dissemination of useful information, not only during an unfolding disaster and immediate recovery period, but often for years, even decades, to come.

Background and context

A technologically advanced but geographically small country with a dense, rapidly-aging and shrinking population, in 2011 Japan had 54 nuclear power plants, which provided 29% of its electricity. The decision to rely on nuclear energy, taken in the 1950s as part of the Atoms for Peace Program, was partly predicated on Japan's geology, which has only very limited fossil fuel deposits that have never been successfully extracted for large scale use, and partly by the desire to pursue a fast path of technology-enabled, power-intensive economic growth (Drash 2011).

As Japan has experienced eight +8 magnitude earthquakes since 1900 (USGS 2012), the safety of the nuclear industry has been a key concern. Although the nuclear power plants did not come under threat during the 6.9 magnitude Kobe earthquake in 1995, some 5000 people died as buildings collapsed, and building codes were significantly strengthened as a result. A Brookings Institution report issued five days after the 2011 earthquake concluded that the early-warning system developed in Kobe's aftermath, which stopped trains and sent a local tsunami warning within three minutes of the quake hitting land, had functioned well (Kaufmann and Penciakova 2011). All 11 nuclear reactors in the area, including those at Fukushima Daiichi, had safely shut down at the first sign of earth movement, as they had been designed to do (World Nuclear Association 2014). However, the resulting tsunami overwhelmed existing seawalls and spread much further inland than expected, resulting in the vast majority of destruction and death (Kaufmann and Penciakova 2011). This flooding caused the backup generators for the reactors' cooling systems to fail.

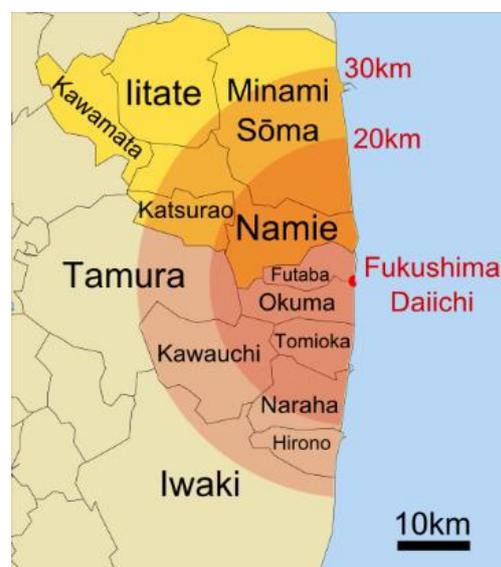
A number of factors complicated the response to the nuclear aspect of the triple disaster, from unprecedented complexity and inability to access the plant itself to ascertain the damage, to long-institutionalised practices within the nuclear industry, such as collusion between regulators, electric

power companies, scientists and even labour unions in keeping information about nuclear safety violations veiled from the public. In part this has been attributed to various factors such as the overly-close ties between groups and organisations producing lax reporting standards and confused lines of responsibility, and involving, for example, exchanges of key safety personnel between regulators and electric power companies (*shukko*), and retirees parachuting from regulatory bodies into executive posts in electric power companies (*amakudari*) (Matanle 2011). These relationships were close enough for the term '*genshiryoku mura*' (nuclear village) to be used to describe the workings of the nuclear industry. The report of the National Diet of Japan's Fukushima Nuclear Accident Independent Investigation Commission (formed by statutory law) admitted that the nuclear part of the triple disaster was 'profoundly manmade' (NAIIC 2012: 9) and recommended that the regulators, the operators and the laws governing the nuclear energy sector all be reformed. The government's own Investigation Committee further concluded that TEPCO had failed to prevent the disaster largely because it was considered too unlikely to be worth the required investment in time, effort or money (ICANPS 2012), despite evidence of earlier destructive tsunamis as recently as 1896 and 1933, and Fukushima's siting directly on the coast.

The dilemma

The Great East Japan (Tōhoku) Earthquake was a magnitude 9.0 undersea earthquake which took place at 14.46pm JST on Friday 11 March, 2011 approximately 70 miles east of Sendai, Honshu (the main island), Japan. The earthquake was the strongest ever recorded in Japan, and the fourth strongest world-wide since record-keeping began in 1900 (USGS 2012). Taking place along a 'subduction zone', where two tectonic plates have overlapped and built up enormous stress over time, the Pacific plate moved approximately 50 meters west, shifting the island of Honshu 2.4m east and tilting the Earth 10cm on its axis (Voigt 2011). However, the majority of the destruction and loss of life occurred during the tsunami which followed, which sent waves up to 33 feet and as far as 10km inland in Miyagi prefecture (COE-DHMA 2011), as well as across the entire Pacific region. Over 100 designated evacuation sites were engulfed by the tsunami (Kyodo 2011), and in the direct aftermath some 370,000 people were displaced.

The Government of Japan declared a State of Nuclear Emergency on Friday, 11 March, due to instability of the reactors at Fukushima Daiichi Nuclear Power Plant, operated by the Tokyo Electric Power Company (TEPCO). The plant is situated directly on the Eastern coast of Fukushima prefecture, 112 km south of Sendai and 270km north of Tokyo, and consists of six reactors, of which three had been online at the time of the earthquake. Although the reactors had all shut down during the earthquake as designed, the earthquake had cut off the power supply for the pumps which controlled the cooling systems for the reactors, and the back-up generators had flooded during the tsunami. As nuclear fuel requires cooling even when the plant is shut down, this was a major concern. A nuclear emergency was immediately declared and residents within a 3k radius were evacuated.



On Saturday, 12 March, the Japanese Nuclear and Industrial Safety Agency (NISA) reported that a hydrogen explosion at 7.30am had damaged the reactor building at Unit 1, but the primary containment vessel had not been breached. Sea water was being injected into the vessel to bring the core temperature down. Authorities extended the evacuation to towns within a 20km radius of the plants, and distributed units of stable iodine to evacuation centres 'as a precautionary measure' (COE-DHMA 2011). On the 13th, a controlled release of vapour into the outer container and sea water injection began at Unit 3 in an attempt to lower pressure and cool the reactor and Chief Cabinet Secretary Edano admitted that a partial meltdown might be underway. At 11am on Monday, 14 March, the IAEA reported a similar explosion at the Unit 3 reactor, followed by an explosion at Unit 2 at 9.14pm which sent a plume of smoke into the air and was deemed to have possibly breached the primary containment vessel. A fire at Unit 4 just before midnight appeared to self-extinguish after approximately two hours. The IAEA's 11 March offer of direct support and co-ordination was now accepted.

By the 17th of March, water levels in all the reactors had become a concern, although the situation was less critical for Units 5 and 6. There were also serious concerns about the integrity of the cores of Units 1, 2 and 3, and water levels and temperatures in the spent nuclear fuel pools at Units 3 and 4. An update on 19 March confirmed that at least some of the fuel in Units 1-3 was exposed, and that there was white smoke coming from Units 2-4. Units 5 and 6 were successfully placed into cold shutdown on 20 March. By mid-May it was determined that the fuel in Unit 1 had been completely uncovered and had probably melted to the bottom of the reactor pressure vessel very early in the accident. Units 2 and 3 also suffered at least partial meltdown of their cores.

In the following days high levels of Iodine-131 and Caesium-137 were detected on the ground at a number of locations close to the plant, in milk and some vegetables produced in the surrounding areas, and at points of the plant where effluent was being discharged into the sea. In April, the IAEA concluded that 'radioactive material from the damaged Fukushima Daiichi plant is gradually spreading outside Japan into the global atmosphere but at extremely low concentrations that do not present health or transportation safety hazards' (IAEA 2011). These levels spiked and then began to decline by the end of May, which was expected as most of the isotopes detected have a short half-life, however evidence of contamination continued to spread. An exclusion area remained, into which some evacuees were allowed in order to retrieve belongings after September. Ultimately, the accident was declared a level 7 on the International Nuclear Event Scale, matched only by Chernobyl, although most later estimates place the total release of radioactivity by the Fukushima disaster at approximately 10% of scale of Chernobyl.

As of March 2016, 15,894 deaths were confirmed with 2,561 people still missing, and close to 230,000 people were still displaced from the region (Japan Times 2016). Almost 130,000 buildings had been destroyed and another 1 million were either partially or significantly damaged. A report released by IAEA in August 2015 concluded that the nuclear disaster was caused in part by inadequate and poorly-implemented regulation, weaknesses in plant design and in emergency management, and a general assumption that Japan's nuclear plants were so safe that a major accident could never happen (IAEA 2015). Although some countries have rolled back their nuclear programmes since, in general civil nuclear programmes worldwide have continued under the assumption that the incident was exceptional and its results 'tolerable' as no one died immediately from exposure to radiation (Downer 2014: 3). Globally, the industry continues to give assurance that it has increased safety measures as a result. However, TEPCO has continued revising its radioactivity data for contaminated groundwater upward, and further events, such as Typhoon Etau, which overwhelmed the drainage systems in September 2015, have driven radioactive water stored at the plant into the sea (McCurry 2015).

At present, decommissioning is still in its early stages, aided by robotics as some of the reactor buildings are still too hot to enter. A sea-side impermeable frozen wall has been completed to stem seepage and a land-side wall is in progress, as well as extensive waterproof paving to mitigate continued contamination by groundwater from the site (METI 2016). In the aftermath of Fukushima, all of Japan's nuclear power plants were shut down for inspection, but so far only 26 have applied to resume operations. Four have returned to active duty but there is considerable pressure to speed up the pace in light of Japan's carbon reduction obligations (NEI 2016).

The role of scientific advice

One significant outcome of the Fukushima disaster was that public trust in scientific knowledge and government advice in Japan was seriously undermined (Grimes et al. 2014). Japan did not, at the time, have a Chief Scientific Advisor, and although the Nuclear Safety Commission and the Science Council of Japan both gave advice to the Cabinet, there were no formal mechanisms in place to channel independent scientific advice to the government or the public (Arimoto and Sato 2012). Within a febrile atmosphere and under rapidly changing conditions, the Japanese public therefore had to rely on media coverage of variable quality and accuracy for information unfiltered by the government or TEPCO. For example, television channels' frequent use of debate style programme formatting meant that the public was given widely diverging and conflicting interpretations by experts of the risks and dangers that the nuclear disaster posed.



The NAIIC (2012) report also points to a situation of distrust between TEPCO's on-site management, the regulatory agencies and the Prime Minister's office in the initial stages of the event, particularly after the latter journeyed to the site to give directions while TEPCO's CEO was in transit and could not be reached. The report suggests that it is likely TEPCO management initially attempted to downplay the seriousness of the event because they believed this was what the government wanted, in the interval when neither the Prime Minister's Nuclear Emergency Response Headquarters, the

Secretariat of the Nuclear Emergency Response Headquarters of NISA, nor the Regional Nuclear Emergency Response team were functioning as planned.

Scientific and technical advice was eventually sought from a number of international sources, including the International Atomic Energy Agency (IAEA), the US Department of Defence, and the World Health Organisation. The IAEA provided daily updates from 11 March until 2 June, tracking the progress of containment activities, based on information provided by Japanese sources, in particular TEPCO and the Nuclear and Industrial Safety Agency (NISA). However, both were deemed by the public to have vested interests in protecting the company, the industry, and the country (Shiroyama 2015), so that within Japan there was not much confidence in the information coming from these sources or from the government. Additionally, as the crisis unfolded, the radiation information released by IAEA became too technical for anyone apart from nuclear scientists to understand, and media coverage aimed at reassuring the public often included engineers who were unprepared for either the media attention or for the kinds of questions about radiation exposure being posed (Oppenheim and Franklin 2016).

In the very confusing aftermath of the explosions at Units 1-3, the UK embassy in Tokyo arranged for a conference call between UK nationals in Japan and Sir John Beddington, the British government's Chief Science Advisor and chair of the Cabinet Office's Scientific Advisory Group for Emergencies (SAGE), which is convened only in times of extreme emergency (see Beddington 2011; Grimes et al. 2014; Oppenheim and Franklin 2016). The call appears to have allayed the fears of many UK expats then in Japan, who were advised they were in no immediate danger of radioactive contamination as long as they remained well outside the evacuation area. Beddington himself was honoured by the Japanese Embassy in 2014 for his part in the effort to promote confidence in the Japanese Government's actions (Embassy of Japan 2014). While there were initially plans to create a similar system of Chief Scientific Advisors, with the election of a new government this seemed to have stalled (Arimoto and Sato 2014). So far, only one science advisor has been appointed, to the Minister of Foreign Affairs (MFAJ 2015).

One of the key continuing problems has been the gathering and dissemination of useful information in languages which are not Japanese, exacerbated by low international collaboration rates and a systemic difficulty in working across disciplines in Japan (Sugiyama et al. 2016). Much of what is available in English is written for nuclear scientists and is therefore indecipherable for policymakers or the general public, while questions about radiation in the exclusion zone only become more crucial as time passes, particularly for evacuees who wish to return. Science advice in this instance has often been a case of double translation, from the technical into the mundane as well as between Japanese and (predominantly) English. The IAEA's (2015) conclusion that levels are in general safe has been contested by Greenpeace (2015) and other organisations, leaving the question of when or whether evacuees will be able to return home largely unresolved. In the meantime, new technical problems have arisen as the decommissioning operation progresses, such as disposition of 1,000 tanks of irradiated water accumulated in the process of cooling the reactors (Mathiesen 2016).

In addition to physical damage, social and economic damage due to mass evacuation will continue to be complicated by Japan's overall trend of depopulation and migration away from rural areas, which had been affecting the Tōhoku region (Matanle 2011). Employment, in particular, has been an ongoing concern, as many jobs have now been permanently lost, and those created by reconstruction cannot be expected to last (Genda 2011). Disagreement amongst medical researchers makes it difficult to predict radiation-related longterm effects (see, for example, Aliyu, et al 2015), while mental and physical illness due to the ongoing stress of evacuation has also been observed (Rubin *et al.* 2012).

Fukushima, therefore, represents not only a need for advice from nuclear scientists and health professionals, but from social scientists as well.



This then begs the question of which advice to follow when experts disagree, and which types of knowledge to prioritise when academic experts diverge in their consideration of issues and problems to resolve. Governments worldwide have also often been accused of choosing to hear only the advice that serves ideologically conceived policy, ignoring that which contradicts their worldview, and academics who raise a dissenting voice may find promotion is denied - hence concerns about the ways that knowledge is interpreted and put to use (Downer 2014), and the potential for regulatory capture and marginalisation of nuclear critics (Kingston, 2014).

Wider lessons and insights

Since 2011, there have been three investigations of the incident, which have come to similar conclusions that there had been a culture in which industry representatives successfully lobbied regulators to promote their company's interests over those of the public, resulting in a downplaying of risk which ultimately compromised safety (Shiroyama 2015). Introducing new regulation may have been seen as a loss of face, an admission that nuclear power was not, in fact, as safe as the government and the industry claimed, and therefore lessons from prior earthquakes were not always put into practice (Thatcher et al. 2015). These investigations resulted in the separation of NISA from the Ministry of Economy, Trade and Industry, and the establishment of an independent Nuclear Regulatory Authority in September 2012.

The problem of industry lobbying, however, is not confined to Japan. An FOI request for emails exchanged between the British government and key players in the nuclear industry in the immediate aftermath of Fukushima suggested that there was great concern within the Department for Business,

Skills and Innovation (BIS) about the adverse effect on Britain's nuclear plans, and BIS was keen to develop a 'joint communications and engagement strategy' to reassure the British public that nuclear power was safe (Edwards 2011). While the 'myth of nuclear safety' may have been stronger in Japan, it is not non-existent in other countries, particularly those which have invested in the 'nuclear renaissance' (World Nuclear Association 2015; Johnson 2015). While Germany decided to phase out nuclear power in the wake of Fukushima, and Spain and Switzerland have banned new construction, some countries – including the UK and the US – have reinvigorated their programmes, citing superior safety regulation, new technology, and the need to transition away from fossil fuels (Johnson 2015). These key lessons from Fukushima, namely a need for robust and independent regulation, clear protocols in the event of an accident, and experts trained in communicating complex and uncertain science to the public, will therefore continue to be of vital importance, particularly in countries pursuing civil nuclear power for the first time.

Finally, there is the question of whether it would be useful to develop formal institutional mechanisms for gathering, analysing and filtering scientific knowledge into advice for governments and other actors to put into practice. Potential models exist in the form of the UN's Inter-Governmental Panel on Climate Change (IPCC), or the UK's Scientific Advisory Group for Emergencies (SAGE). Five years after the Fukushima crisis exposed the fragility of the role of scientific advice in Japan, the country still grapples with the question of how to put an effective system in place.

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QUESTIONS FOR REFLECTION

- Incidents at the plant were unfolding very quickly in the first days. How soon should scientific advisors become involved and with whom? Should their expertise be directed solely at decision makers, or do they have a significant role to play with regard to clarifying an unfolding situation for the media and the public?
- How might the international nature of the issue affect the role of the Chief Scientific advisor in this case? To what extent might preserving the sovereignty or reputation of the country influence the ability to speak freely and to whom?
- Public trust in risky technology is often predicated on trust in regulatory bodies for setting adequate levels for safety and enforcing regulation in the public interest. Regulators, however, are also tasked with ensuring that the industry can function economically. To what extent can scientific advice help with the setting of reasonable regulatory goals?
- What kind of science advice will continue be required as evacuated residents return home? How should 'safe' levels of radiation exposure be communicated and what kind(s) of support systems should be in place for continued monitoring of the health of residents and workers, without causing undue concern?
- What mechanisms are required for accurate scientific knowledge and advice to be channelled to governments and the public prior to and during emergencies? How should these mechanisms be structured? And what are the potential difficulties involved in developing these systems?

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PHOTO CREDITS

- COVER: Reactor Units 3 and 4 at Fukushima Dai-ichi after Tōhoku earthquake and tsunami, 16 March 2011. Credit: Digital Globe, CC BY-SA 3.0. Source: <http://www.flickr.com/photos/digitalglobe-imagery/5530841229/in/>
- PAGE 3: Japan towns, villages, and cities in and around the Daiichi nuclear plant exclusion zone. Credit: Mayhew, derived from Lincun -CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=15005400>
- PAGES 5 and 7: Shore area, Ishinomaki City, August 2011. Credit: Peter Matanle, CC BY-NC-SA.



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- Collaborating with other organisations where there are common or overlapping interests;
- Assisting the development of advisory systems through capacity-building workshops;
- Producing articles and discussion papers based on comparative research into the science and art of scientific advice.

Anyone with an interest in sharing professional experience, building capacity and developing theoretical and practical approaches to government science advice is welcome to join INGSA.

By signing up to the INGSA Network you will receive updates about our news and events and learn of opportunities to get involved in collaborative projects.

Go to <http://www.ingsa.org> for more information.

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