



Treated water releases from the Fukushima Dai'ichi nuclear power plant: An overview of the decision-making process and governing institutions

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ABSTRACT

In August 2023, the Tokyo Electric Power Company (TEPCO), with permission of the Japanese government, began to release treated water stored on the site of the Fukushima Dai'ichi nuclear power plant into the Pacific Ocean. Given their unprecedented nature in terms of scale and duration, with over one million tons of water to be released over thirty years, the releases have drawn international scholarly attention from marine policy, law, conservation and social sciences, as well as from policy and science-media sectors more widely. The purpose of this communication is therefore to provide an international audience with an outline of the processes through which the decision to release the treated water was made; and of the institutions and policy frameworks that govern the treated water releases from Fukushima Dai'ichi.

1. Introduction

The Fukushima Dai'ichi nuclear disaster is one of the largest accidental marine contamination events ever. The Great East Japan Earthquake and Tsunami of March 2011 disabled cooling systems at the Fukushima Dai'ichi nuclear power plant, leading to hydrogen explosions which released large amounts of radioactive material over the north-west Pacific Ocean [46].

The situation at the plant has stabilised, and radioactivity in the marine environment has declined [47]. Yet there is still a need to store water containing radioactive substances on-site that has been recovered from groundwater or pumped through the damaged reactors to keep them cool. Amidst concern that space to store the treated water at the Fukushima Dai'ichi site will run out, the Japanese government (specifically, the Cabinet of the Prime Minister) in spring 2021 approved the recommendation of the Ministry of Economy, Trade and Industry (METI) and the Tokyo Electric Power Company (TEPCO) to release treated water into the ocean, a proposal based on the advice of a technical committee convened by METI. This decision was then approved by Japan's Nuclear Regulation Authority in 2022, and releases of treated water into the north-west Pacific Ocean began in August 2023.

The decision to release the treated water has attracted significant scholarly attention across marine policy, law, conservation, and social sciences, as well as in the wider media and political spheres, both within Japan and globally. The purpose of this communication is therefore to outline the processes through which the decision to release the treated

water was made; and provide an overview of the institutions and policy frameworks that govern the treated water releases from Fukushima Dai'ichi.

2. Background and context

The Fukushima Dai'ichi nuclear power plant is located on the coast of Fukushima Prefecture in north-east Japan, about 250 km north-east of Tokyo. Straddling Okuma and Futaba Towns in Futaba District, the plant consisted of six reactors and was commissioned in 1971. On 11 March 2011, the Great East Japan Earthquake and Tsunami disabled cooling systems at the plant, leading to two hydrogen explosions and three partial meltdowns. Around 70–80% of the radioactive material released from Fukushima Dai'ichi following the disaster went into the north-west Pacific Ocean [50], making the Fukushima Dai'ichi meltdowns one of the largest accidental marine contamination events ever.

As the situation at the plant has stabilised and as marine radioactivity in Fukushima seas has subsided and come to be better understood, coastal fisheries on the Fukushima coast have resumed and gradually expanded back towards pre-disaster levels [23]. However, water still needs to be pumped through the damaged reactors to keep them cool, and groundwaters under the plant contaminated immediately after the accident have had to be recovered. As this water has come into contact with the highly radioactive reactor cores, even after processing to remove some of the most harmful radionuclides it has had to be stored in tanks on the Fukushima Dai'ichi site [3]. The sheer volume of water

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required to keep the reactors cool (over 1000 tanks and 1 million tons [24]), and the fact this water is constantly being produced, means that space on the Fukushima Dai'ichi site to store the water is running out. A governmental advisory committee in 2020 concluded that discharge into the sea and vapour release were the only viable options for disposing of the water [31], ruling out options such as expanding the storage tank site on land or solidifying treated water in concrete.

3. Regulations, policies and processes leading up to the releases

3.1. Domestic regulations and policies, and on-site processes

Within Japan, TEPCO is responsible for managing the plant itself; and METI is responsible for overseeing TEPCO's activities on the Fukushima Dai'ichi site [25,26]. The Ministry of Environment has responsibility for conducting marine environmental monitoring to confirm the status of radioactivity in the environment, including from treated water [27]; and also hosts the Nuclear Regulation Authority, the administrative body which approves nuclear safety processes. The Cabinet of the Prime Minister has final authority on decisions to release treated water.

When the recommendation of METI and TEPCO to release treated water into the Pacific was approved by the Cabinet of the Prime Minister, the 'Basic Policy on handling of ALPS treated water at the Tokyo Electric Power Company Holdings' Fukushima Daiichi Nuclear Power Station' [15] was adopted on 13 April 2021. Physical preparations then began for releasing the treated water. A 1 km sub-seabed tunnel was bored from land on the Fukushima Dai'ichi site out into the sea, through which treated water is released into the Pacific Ocean after dilution. TEPCO uses its advanced liquid-processing system (ALPS) to remove strontium, caesium and most radioactive substances except tritium (which is difficult to remove due to its chemical properties) from the water prior to release [44], and further dilutes the treated water prior to release into the sea to a tritium concentration of around 150–200 Becquerels per litre (Bq/l), in comparison to the Japanese regulatory limit of 60,000 Bq/l [43].

Prior to the commencement of releases, around 1.3 million tons of water were stored on the Fukushima Dai'ichi site in over 1000 tanks [24]. Because the water needs to be treated and then diluted before being released into the sea, and to allow monitoring of any effects on the marine environment in the early stages of the releases especially [41], water is being released into the Pacific Ocean in batches. For example, TEPCO discharged 7800 tons of treated water in each of the first two release rounds in autumn 2023 [48]. As the water is being released in batches, and as additional treated water is being produced in the meantime due to the need to continually pump water to keep the damaged reactors cool, the entire release process is expected to continue for several decades.

3.2. The role of the IAEA

At the same time as the 2021 recommendation to release treated water was approved, the International Atomic Energy Agency (IAEA), at the request of the Japanese government and TEPCO, formed a taskforce to advise on the treated water releases. Unlike the expert committees formed within Japan, whose recommendations feed into specific pieces of domestic policy and legislation guiding the treated water releases (see e.g. the various committees advising on different aspects of the treated water releases and decommissioning of Fukushima Dai'ichi more broadly [25,26]), the recommendations of the IAEA taskforce and indeed the wider work of the IAEA at Fukushima Dai'ichi are advisory. Final decisions over how to process the treated water rest with the Japanese government and TEPCO. In early July 2023, the IAEA presented the Japanese government with its final Comprehensive Report on the Safety Review of the ALPS-Treated Water at the Fukushima Daiichi Nuclear Power Station [12]. This was a technical report, focusing on the

physical processes of treating and releasing the water itself and on the potential for any harm to humans and ecosystems arising from the releases. Following the presentation of the IAEA report, the Japanese Prime Minister and government confirmed the plans to release the treated water, and after final inspection of release equipment on-site and the granting of a permit to TEPCO to conduct the releases, commenced the release of treated water on 24 August 2023.

The IAEA report concluded that TEPCO's protocols for releasing treated water were in line with the range of eleven international standards used by the IAEA to ensure protection of health and minimization of danger to life and property [12]. These include, for example, the IAEA-UN Environment Programme (UNEP) standard on 'Regulatory Control of Radioactive Discharges to the Environment' [22]; and the 2014 'Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards' agreed by the European Commission, UN Food and Agriculture Organization, IAEA, OECD Nuclear Energy Agency, Pan-American Health Organization, UNEP, and the World Health Organization [14].

As part of gaining the necessary domestic permissions to release the treated water, TEPCO published a Radiological Environmental Impact Assessment (REIA) [42]. The REIA assesses the radiological impacts on humans, marine plants and animals from the release of ALPS-treated water under the approach proposed by TEPCO. The assessment claims that (a) the radiological impact on people most likely to be affected is minimal; (b) the exposure level for plants and animals inhabiting the 10 km x 10 km sea area around Fukushima Dai'ichi is well below the threshold at which deleterious effects from exposure may be expected; and (c) impacts on areas far from the discharge point, in other words transboundary impacts, are undetectably low [42]. IAEA [12] reviewed the TEPCO REIA, including dose rates for the reference species of flat fish (left-eyed and right-eyed flounders, *Paralichthys olivaceus* and *Pleuronectes platessa* respectively), crabs (*Ovalipes punctatus* and *Portunus trituberculatus*) and brown seaweed (*Sargassum fulvellum* and *Eisenia bicyclis*), against the International Commission on Radiological Protection dose limits and approach for the protection of the environment. From its review, the IAEA too concluded that the risk of harm to humans or ecosystems from the releases is negligible. Following the first Task Force review mission to Fukushima Dai'ichi after the start of the treated water releases, the IAEA [13] reported that initial observations are in line with the REIA, but that empirical observations can be used to review and update the REIA (as is required periodically under the IAEA Safety Standards). The IAEA Task Force expressed particular interest in assessing accumulation of radionuclides in marine sediments versus assumptions made in the REIA and its underlying models, but acknowledged robust verification is likely to be difficult due to low quantities discharged and further dilution in the sea.

International reaction to TEPCO's REIA and the IAEA report was not so uniformly positive. International environmental non-governmental organisation Greenpeace [10] argued that the IAEA failed to investigate the operation of ALPS itself, and that TEPCO's release plan fell short of a full environmental impact assessment. Korean newspaper Hankyoreh [11] expanded by claiming that the REIA, which is based on marine dispersion models, does not take into account effects on marine ecosystems or neighbouring countries further away from Fukushima Dai'ichi, such as South Korea. Suzuki [40] similarly commented that although the IAEA review of TEPCO's plan was helpful, it only verified the samples provided by TEPCO for the first discharge and did not review the entire plan which could continue for the next thirty years. The not-for-profit environmental data organisation Safecast [37], meanwhile, noted that the IAEA comprehensive report is clear about its own limitations, and that many significant aspects of the decision-making process around the releases – such as possible alternatives, justification for the releases, and ethical aspects – lie outside the scope of the IAEA review work and are the responsibility of government agencies within Japan. Safecast also draw attention, however, to the IAEA Task Force recommendation to TEPCO for more consideration to be given to

radionuclides within the released treated water that are not tritium, which behave differently in the environment to tritium and are taken into the food chain differently.

In early July 2023, the IAEA Director-General met with key local stakeholders in Fukushima Prefecture, including fishers and municipal governments, and the IAEA announced they would set up a permanent office on the site of Fukushima Dai'ichi provide continuous monitoring and oversight for the duration of the releases. The IAEA is continuing to sample sea water, marine sediment and fish from around the Fukushima Dai'ichi site as it has done since 2015, and is also sampling fish from fish markets in Fukushima Prefecture. IAEA monitoring focuses on six fish species - olive flounder (*Paralichthys olivaceus*), crimson sea bream (*Eymnis tumifrons*), redwing searobin (*Lepidotrigla microptera*), Japanese jack mackerel (*Trachurus japonicus*), silver croaker (*Pennahia argentata*) and vermiculated puffer fish (*Takifugu vermicularis*) – known to have higher radioactivity because of the areas of the sea they move around in, and is being undertaken at the request of the Japanese government to build confidence in the marine radioactivity data Japan provides [49].

4. What does the science say?

This section is not a comprehensive or exhaustive review of the science associated with the Fukushima Dai'ichi nuclear accident or the releases of treated water. The aim, rather, is to highlight the key areas of concern and contention among different researchers globally on the effects of the treated water releases on the marine environment, and on the rigour and quality of the monitoring and contingency plans put in place by TEPCO. As above, the IAEA's final comprehensive report concludes that the release protocol is in line with a suite of international standards, and that risk of harm to humans or ecosystems is minimal [12]. Similarly, the views of several individual scientists commenting separately across science media suggest that if managed properly, the risk of harm to humans and ecosystems from the releases should be negligible [30,38]. Yet, Section 3.2. also shows other researchers and environmental NGOs have identified areas where the robustness and extent of the monitoring regimes in place could be improved.

Plant operator TEPCO has undertaken experiments on-site, raising flounders (*Paralichthys olivaceus*) in pools of water with concentrations of tritium up to 1500 Bq/kg (the Japanese regulatory maximum concentration allowed for release) and comparing these to control samples raised in normal sea water to assess the effects of tritium on marine species. Flounders were selected as a reference species as they widely inhabit the sea around FNDPP [12,42], and as bottom feeders are a point at which radionuclides can enter the food chain via accumulation on sediment. Based on their experiments, TEPCO claims that they believe tritium does not accumulate and concentrate in the body of flounders [45]. TEPCO has undertaken similar experiments with abalone as a shell fish (*Haliotis*) and sea lettuce and Sargassum as seaweeds (*Ulva Linnaeus* and *Sargassum fulvellum*). It is worth remembering that although TEPCO's reporting and underpinning research is carried out by industry experts, it is industry research carried out by the plant operator and as such as not an independent assessment.

However, a short two-page position paper by the US National Association of Marine Laboratories – an organisation of non-profit marine laboratories across the United States - expressed concern over the data provided by TEPCO and the Japanese government in support of the decision to release the treated water. The position paper argues there are flaws in sampling protocols, statistical design and analysis used by TEPCO; and questions the assumption that dilution of treated water is sufficient to negate the risk of harm given the long half-life (decades to centuries) of some of the radionuclides as well as processes of bio-accumulation and concentration in seafloor sediments [28]. The NAML position paper also explains the Pacific is the largest continuous body of water on the planet, with 70% of the world's fisheries. Indeed, the Pacific Islands Forum, which represents Pacific Island nations, appointed a panel of international scientists to advise on the potential effects of the

releases on Pacific Islands, highlighting the importance of protecting the Pacific from further nuclear contamination [32]. It is also worth bearing in mind that even in the presence of multiple international standards for radiological protection which the IAEA drew on to conclude that the risk of harm from the releases is negligible, the release of more than one million tons of treated water into the ocean over several decades of the kind planned at Fukushima Dai'ichi is unprecedented [3,4].

There is, however, a range of data from governmental sources in Japan which can provide a pre-2011 baseline for marine environmental radioactivity; and a view of marine environmental radioactivity since the accident but before the treated water releases commenced. The Hydrographic and Oceanographic Department of the Japan Coast Guard has conducted annual monitoring for radioactivity at points around Japan's offshore waters for seawater and seabed since 1959 and 1973 respectively [17]. Since 2011, Fukushima Prefecture have conducted regular monitoring of seawater, sediment and multiple marine species [9]; whereas the Fisheries Agency of Japan have monitored fisheries produce in Fukushima and nearby prefectures in north-east Japan [6]. These all provide data sources which allow the changes in environmental conditions following the releases of wastewater to be assessed.

5. Continued local concern

Fukushima's fishers, specifically the Fukushima Prefectural Federation of Fisheries Cooperative Associations, remain opposed to the releases of treated water. The federation voted unanimously in early July 2023 to oppose the releases following a similar decision from Japan's nation-wide federation of fisheries cooperative associations [7]; but have stated that they intend to continue fishing operations on the same basis as before the releases commenced [8]. Fishers' opposition to the releases are based largely on concern over effects on the sales and prices of Fukushima seafood if the treated water releases lead to Fukushima marine produce being perceived as 'tainted.' The Japanese government had, by autumn 2023, pledged ¥100 billion in aid to support Japan's fishing sector against any loss in revenue that arises from lower prices or loss of international sales due to the releases [18].

Fukushima's fishers expressed particular opposition to how the decision-making process for treated water proceeded. The first formal meeting between TEPCO and fisheries stakeholders was not scheduled until August 2021, by which time METI and TEPCO had already received government approval for the recommendation to release the treated water and many of the technical details of the releases were in planning [35]. Despite a face-to-face meeting with the Japanese Prime Minister days before the releases began, Japan's national fisheries federation remained opposed to the releases at the time of commencement [19]; and fishers in Fukushima Prefecture expressed disappointment that the Japanese government was perceived as having broken its promise not to start the releases without the support of all parties [21].

Fukushima Prefecture has remained largely neutral towards the releases other than to call for dialogue with and respect for fishers [19]. However, a number of municipal governments (i.e. at the town and village level) within the prefecture stated their opposition to the releases, expressing a preference for a land-based storage option for the treated water and claiming that the decision to release treated water is a major setback to hopes of local revitalisation after the nuclear disaster [1]. In autumn 2023, a group of Japanese citizens and fisheries stakeholders submitted a complaint against the Japanese government and TEPCO to request an injunction to the releases, claiming that the releases contravene 'right to a peaceful life' and also the London Convention and London Protocol [29] – although as Nishikawa and Hesselman note, whether the Fukushima Dai'ichi treated water releases fall under the London Convention and its Protocol or not is a matter of debate [16].

However, whilst the fisheries cooperatives and municipal governments can register their opposition or concern to the releases, TEPCO and the national government are not legally obliged to obtain their

consent. TEPCO, the Japanese government, the Fukushima Prefectural Federation of Fisheries Cooperative Associations and to a lesser extent Fukushima Prefectural Government have all committed to undertake information provision and engagement to counter any reputational damage to Fukushima marine produce that may arise as a result of the releases.

Moreover, what is less clear is how TEPCO or the Japanese government may handle any environmental damage. TEPCO's implementation plan and the IAEA comprehensive review note that there are measures in place to prevent un-diluted water entering the sea and to identify and stop releases quickly should abnormalities be detected [12,41]. TEPCO also state in their implementation plan that initial releases are being undertaken in small batches to allow effects on the environment to be assessed; and that releases will be stopped if any abnormalities are detected during marine monitoring [41]. However, measures to attempt to remediate any environmental damage should it arise, or whether alternative methods of disposal would be sought should the releases into the sea be deemed to be unviable, are much less explicit.

6. International responses

Two of the most vocal opponents to the treated water releases internationally have been South Korea and China. In addition to the IAEA report, South Korea completed its own assessment of the proposed treated water releases in 2023, which included sending its own team of experts to Fukushima Prefecture. Based on the IAEA report and the outcomes of its own assessments, South Korea in July 2023 agreed that the plan for releases complies with the global safety standards outlined by the IAEA, and that the country respected the IAEA's approval for the releases [34]. However, a ban on seafood and other foods from Fukushima Prefecture in South Korea remained in place given a lack of evidence indicating that associated risks have been eliminated [34,36]. China, meanwhile, remains strongly opposed to the releases, claiming that Japan is transferring the risk of contamination to the wider world. As well as maintaining a ban on produce from Fukushima Prefecture, China announced stronger inspection measures in July 2023 for products from 37 of Japan's 47 prefectures, with the possibility of further measures depending on developments relating to the treated water releases [20]. Similarly, as outlined above, the Pacific Islands Forum – a political and economic policy organisation representing Pacific Islands – have expressed concern over the precedent the treated water releases may set, calling for a precautionary approach and reminding Japan and the international community of the importance of the marine environment to Pacific Islanders' livelihoods [33].

7. What next?

The treated water releases are now underway, and initial data suggests there are no immediate effects on people or the marine ecosystem [5]. However, there is a need to pay attention to radionuclides other than tritium [3]; cumulative effects on the marine environment from radionuclides over time [28]; and complex migration pathways of marine species [39]. In addition to marine monitoring data which is provided by TEPCO and national-level environmental institutions in Japan, the IAEA has established a permanent presence at Fukushima Dai'ichi and stated its intention to continue monitoring throughout the duration of the releases. Independent data, ideally involving local residents and fishers in collection and analysis, will be important to maintain trust in the monitoring results [2,3]. Similarly, whilst initial media attention over the releases has subsided, another vital issue going forwards is monitoring the uptake and pricing of seafood landed in Fukushima ports, both within Japan and overseas; and also observing the social and cultural impacts on Fukushima Prefecture's coastal communities (e.g. stigmatisation, sense of pride and identity) should any negative perception of Fukushima marine produce occur. Lastly, whilst the releases do at present appear to be proceeding according to plan, the

unprecedented nature of the releases should not be forgotten, nor should the fact that unexpected events may occur during the 30-year timeframe of the releases [4]. Continual planning from TEPCO and from the Japanese government for countermeasures and remediation action to be taken should any anomalies in the marine environment be discovered is thus vital.

CRedit authorship contribution statement

Leslie Mabon: Writing – review & editing, Writing – original draft, Project administration, Investigation, Funding acquisition, Conceptualization.

Declaration of Competing Interest

The author hereby declares that he does not stand to gain financially from any actions taken on the basis of the content of this text; and that no funder or institution has had any influence over the conceptualisation, design or writing up of this text.

Data availability

No data was used for the research described in the article.

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