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Stemming the tide 2020

The reality of the Fukushima radioactive water crisis

Shaun Burnie
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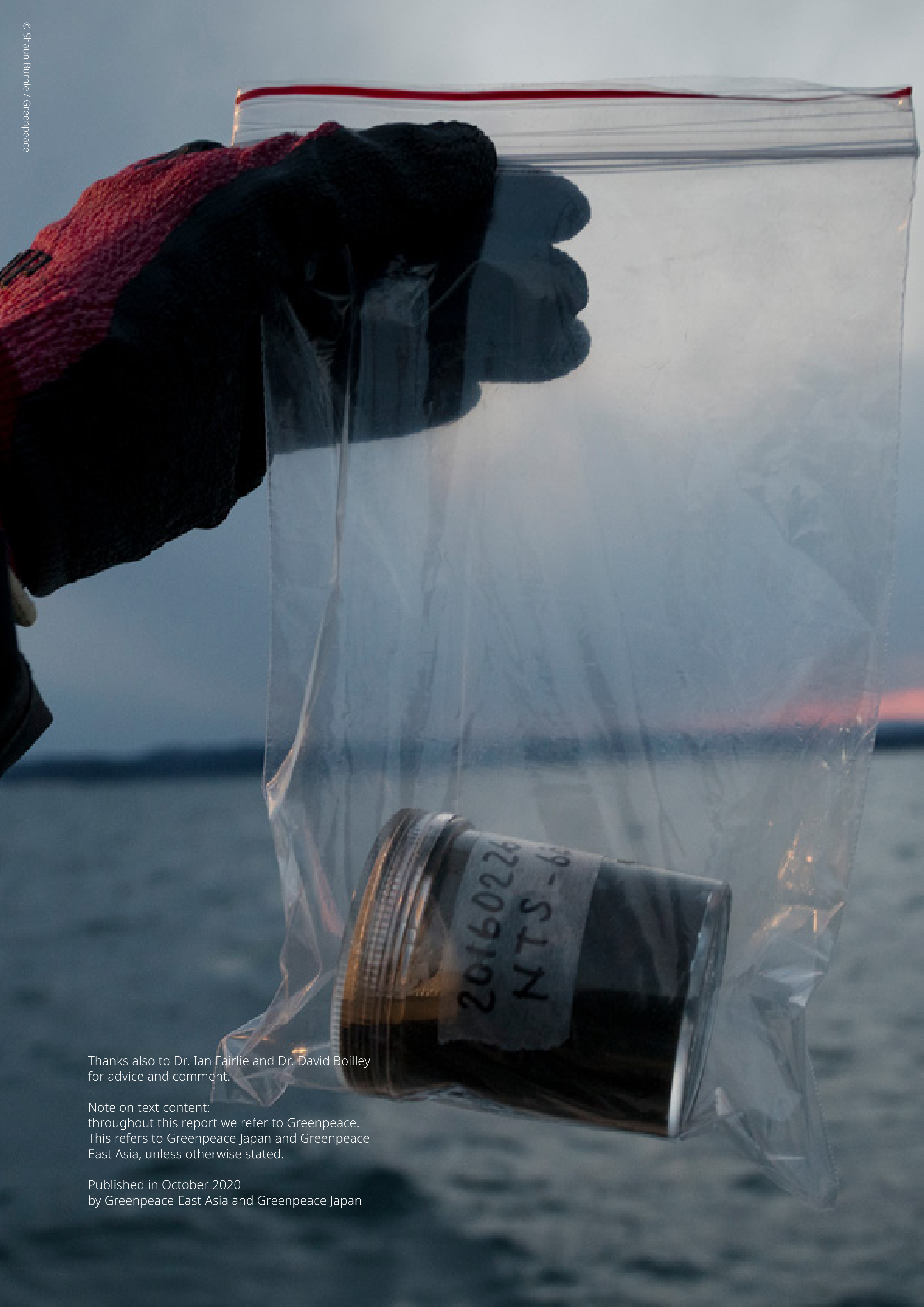

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Note on text content:
throughout this report we refer to Greenpeace.
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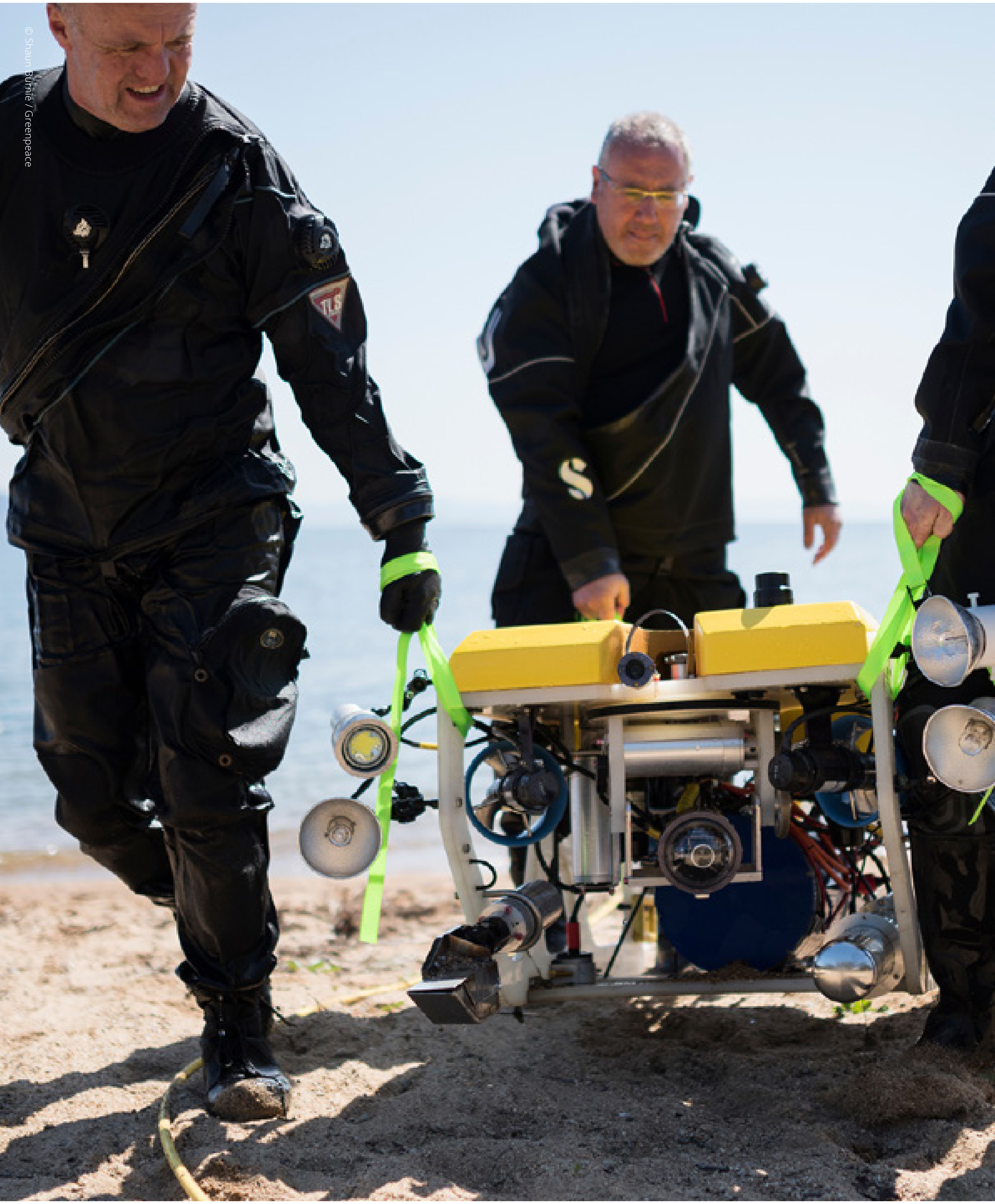
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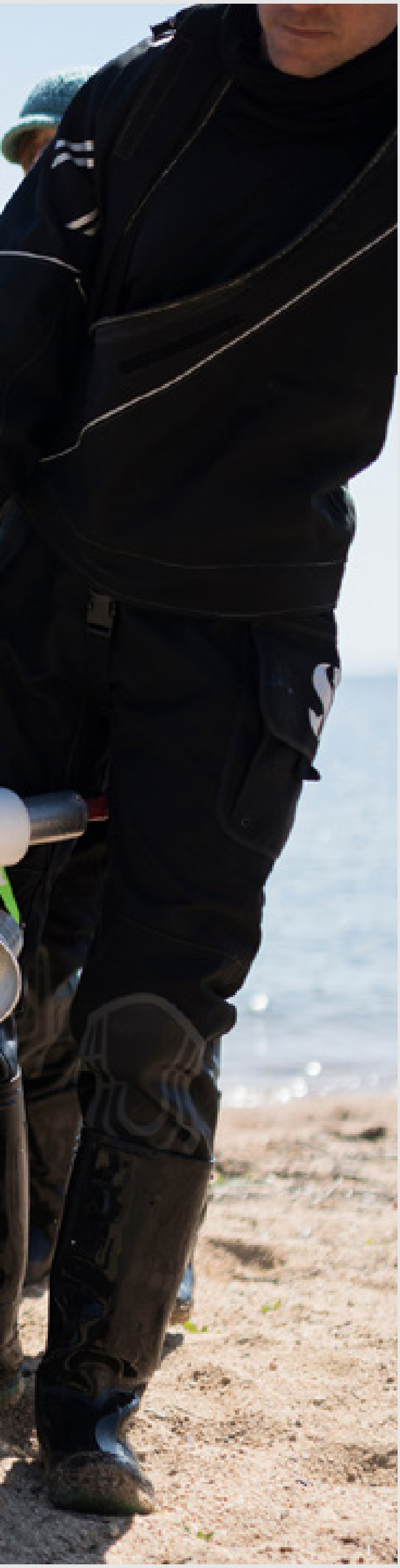


Overview

Two years after our first report on the crisis,[1] more than a million tons of radioactive water is still sitting in tanks at the Fukushima Daiichi nuclear power plant in Japan, site of the catastrophic meltdown in March 2011. The Japanese government has decided that it will discharge the contaminated water into the Pacific Ocean, releasing strontium-90, carbon-14 and other hazardous radionuclides. It is a move that will have serious, long-term consequences for communities and the environment, locally and much further afield. Currently, discharges are planned to begin in late 2022 or early 2023, and these will continue until the mid-2050s.

The Japanese government and the Tokyo Electric Power Company (TEPCO) have constructed a series of myths to support their plan: that by 2022, there will be no further space for storage of the water; the water is not contaminated – radioactive tritium is the only radionuclide in the water and it is harmless; and there are no alternatives to discharging the water into the ocean.

This report, as did our 2019 analysis, demonstrates that these statements are untrue. The Japanese government's narrative has been created for both financial and political reasons. Not only is ocean discharge the cheapest option, it helps the government create the impression that substantial progress is being made in the early decommissioning of the Fukushima Daiichi reactors. But long after the Suga and Abe administrations are historical footnotes, the consequences of the nuclear disaster will remain a constant threat, most immediately to the people and environment of Fukushima, but also more widely in Japan and internationally.

Any government or industry confronted by the scale and range of challenges would have struggled to manage the disaster. However, time after time, TEPCO and Japanese government bodies appear to have conspired to make the crisis worse. TEPCO's recent admission that their processing technology is flawed, and the acknowledgement, almost 10 years after the disaster, that the water contains radioactive carbon-14 are just the latest in a long history of misreporting and cover-ups.[2]

There has been sustained opposition to the discharge of the contaminated water from citizens in Fukushima, commercial bodies such as Japan's national federation of fisheries cooperatives, JF Zengyoren,[3] the majority of municipal assemblies in Fukushima Prefecture, and wider Japanese society. There has also been opposition from Japan's nearest geographical neighbours, especially the Republic of Korea. However, the Japanese government continues to ignore the views of all who seek to protect the world's oceans.

After a detailed examination of the evidence, Greenpeace has concluded that the only acceptable solution is continued long-term storage and processing of the contaminated water. This is logistically possible, and it will allow time for more efficient processing technology to be deployed as well as allowing the threat from radioactive tritium to diminish naturally. It is the only way to safeguard the human rights, health and environment of the people of Fukushima, the rest of Japan and the wider international community.

Main findings

Contaminated groundwater continues to accumulate

* While the volume of groundwater flowing from the mountains and flood plains of Fukushima into the site has been reduced, the average daily rate in 2019 was 180 cubic meters (m^3). This increases dramatically following typhoons – Typhoon Hagibis in October 2019 led to over 650m^3 entering per day. The total amount of contaminated water is expected to rise to 1.37 million m^3 by the end of 2020.
* The primary source of radioactivity remains the melted nuclear fuel or corium located at the three Fukushima Daiichi reactors. Fresh groundwater entering the site continues to become contaminated as a result. It's estimated that this will lead to an additional 500,000 tons, perhaps as much as one million tons, of contaminated water accumulating by 2030.[4]

The Advanced Liquid Processing System (ALPS) is flawed

* In terms of ALPS performance, and following research by consulting engineer, the late John Large,[5] we explain how TEPCO rejected using ion exchange technology from US. supplier Purolite despite its technology showing in 2011 that it could reduce concentrations of radionuclides in the contaminated water to Non-Detectable levels.
* The resultant poor performance of the ALPS, operated by Toshiba and Hitachi General Nuclear Electric (HGNE), both of which had practically no experience in water processing, is likely to have its root cause in the decision to exclude Purolite.
* Due to the failure of ALPS, 72% of the water currently in storage tanks is required to be processed again. There remain serious questions over how effective this will be. A test programme in October 2020 is to be followed by the processing of more than 800,000 tons of contaminated water.

The dangers of carbon-14 and tritium in the water are being ignored

* In addition to high levels of hazardous radionuclides such as strontium-90, TEPCO on 27 August 2020 acknowledged for the first time the presence of high levels of carbon-14 in the contaminated tank water.[6]
* ALPS was not designed to remove carbon-14 despite it being a long term radiological hazard. Carbon-14 is integrated in the carbon cycle, which is very complex due to the presence of inorganic and organic carbon, in solid, liquid or gaseous forms. Put simply, carbon-14 is incorporated into all living matter to varying factors of concentration. Claims by the Japanese government that the Fukushima Daiichi ALPS tank water is not contaminated water are clearly wrong.
* If the contaminated water is discharged to the Pacific Ocean, all of the carbon-14 will be released to the environment. With a half-life of 5,730 years, carbon-14 is a major contributor to global human collective dose; once introduced into the environment it will be delivered to local, regional and global populations for many generations.[7]
* TEPCO and the Japanese government have so far failed to explain to the citizens of Fukushima, wider Japan and internationally that the contaminated water to be released into the Pacific Ocean contains dangerous levels of carbon-14.
* The Japanese Ministry of Foreign Affairs (MOFA) has continued to mislead the United Nations human rights Special Rapporteurs when questioned over the Fukushima Daiichi contaminated water. For example, MOFA's statement in June 2020 that, "After most of the radionuclides except tritium are removed in this purification system (ALPS), the water is safely stored in

the tanks as ALPS treated water…Therefore ALPS treated water stored in the tanks is not contaminated water.[8]

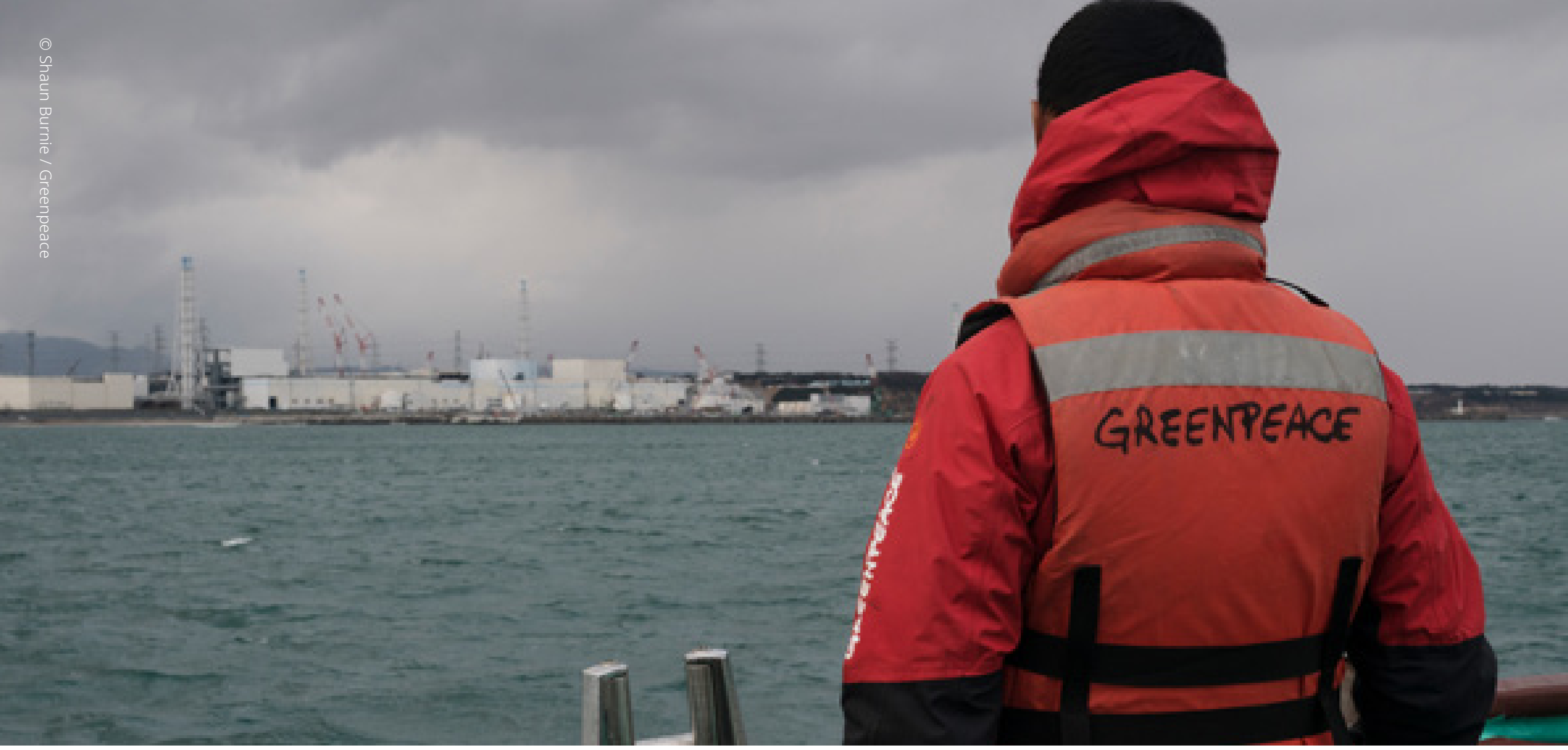
* Contrary to the understanding of the Japanese government, water that contains large quantities of radioactive carbon-14 (as well as the other radioactive isotopes including strontium-90 and tritium) can only be described as contaminated.
* TEPCO continues to misrepresent and selectively ignore basic science facts on radioactive tritium. In particular, they continue to ignore and fail to explain the role of Organically Bound Tritium (OBT), and consequently are not providing accurate scientific data on the potential impacts of any future releases of contaminated water.
* Current human dose models used by the IAEA (and the Japanese authorities and TEPCO) are based on single discharges, but when multiple discharges occur the levels of OBT build up gradually.[9]
* There can be no justification for the failure of the Japanese government and TEPCO to fully explain the potential impacts of radioactive tritium discharges into the environment, including OBT.

Storage is a viable option

* Our analysis of the Ministry of Economy, Trade and Industry (METI) Subcommittee on Contaminated Water report shows it understood that additional storage for the contaminated water beyond 2022 was possible both on and off the site, but ruled it out as it would take "a substantial amount of coordination and time".
* The Subcommittee confirmed that longer storage of the ALPS-treated water would at least reduce the radiological hazard due to tritium. Tritium has a short half-life (12.3 years) and based on an annual discharge of 22TBq, METI's own data shows that delaying the start of discharges would allow the tritium to diminish naturally so that, if discharges began in 2035, they would be completed only three years later (2055) than if they were to begin in 2020.
* The METI Subcommittee's recommendation to discharge the contaminated water into the environment was clearly not based on science and engineering, but on the political interest of the Japanese government and the future viability of TEPCO.

Local views and human rights issues are being ignored

* There is strong local opposition to any discharge into the environment, including from municipal assemblies, fisheries associations, and citizens. The former UN Special Rapporteur on disposal of hazardous substances and wastes, Baskut Tuncak, stated: "It is their human right to an environment that allows for living a life in dignity, to enjoy their culture, and to not be exposed deliberately to additional radioactive contamination. Those rights should be fully respected and not be disregarded by the government in Tokyo."[10]



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Current status

According to TEPCO, as of 20 August 2020, water is stored in 1,041 tanks on the Fukushima Daiichi site. These consist of 944 tanks with ALPS-treated water, 71 tanks with caesium/strontium-treated water, 24 tanks containing fresh water treated with the reverse osmosis facility, and 2 tanks for concentrated seawater.[11] The total amount of contaminated water held was 1,235,907m³. [12] In addition, highly contaminated water remains accumulated in the nuclear reactor basements and other places – in August 2020 TEPCO reported that as much as 17,010m³ was in storage.[13] There is a risk that this water could leak directly into the ground and the Pacific Ocean.

TEPCO continues to pump tons of water a day into the destroyed reactor pressure vessels (RPV) of units 1-3 in an effort to cool the melted reactor fuel or corium (a combination of molten fuel, concrete and steel). The estimated amount of corium in Fukushima Daiichi reactor units 1-3 ranges from 609 tons to 1,141 tons. With a nominal sum value of 880 tons, it is 3.4 times more than the original fuel in the three reactors.[14] This cooling water therefore becomes highly contaminated.

While the volume of groundwater that flows from the mountains and flood plains of Fukushima onto the site has been reduced, the average daily amount entering the reactor buildings in 2019 was 180m³. This increases dramatically when there are heavy rains, including from the frequent typhoons. Failure to prevent future groundwater contamination will lead to an estimated additional 800,000 tons of contaminated water accumulating by 2030.[15] The more than a million tons of highly contaminated water that the Japanese government is threatening to discharge into the Pacific Ocean could become 2 million tons within the next 10 years. Annual cost of water storage is currently running at slightly over 100bn yen (US$ 900m) a year.[16]

Reactor pressure vessel (RVP) cooling

As of 14 September 2020, cooling water was being injected into the RPV at the rate of 2.8 cubic metres per hour (m³/h) for unit 1, 2.8m³/h for unit 2 and 3.1m³/h for unit 3.[17] At 216 m³/day, the average weekly amount of water circulated in the three-reactor cooling system is 1,512 m³. Temperature ranges at the bottom of the RPV are between 27C and 36C.

The problem of groundwater/ rainwater entering reactor buildings

The proposals to discharge contaminated water stored in tanks at Fukushima Daiichi do not solve the fundamental problem that contaminated water continues to accumulate every day. As detailed in our 2019 report, measures taken by TEPCO have resulted in significant reductions since the early years following the start of the nuclear accident.

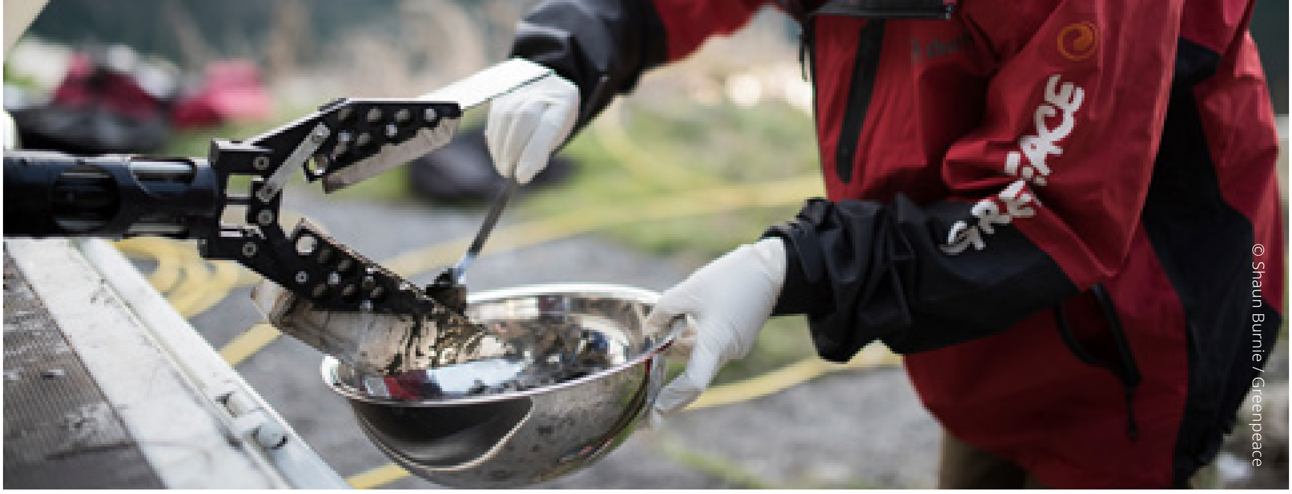
For many years, TEPCO was not explicit about groundwater entering the site coming into direct contact with water pumped into the reactor pressure vessels. However, it now openly states that, "groundwater flowing from the mountainside infiltrates the reactor buildings and becomes mixed with water for cooling the fuel that melted due to the accident and then hardened, resulting in daily generation of water containing high-level radioactive materials ('contaminated water')."

The groundwater problem remains unresolved and therefore, even with a decision on disposal of tank-stored water, contaminated water will continue to accumulate. There are major variations in groundwater and rainwater entering the site, linked to weather and seasonal factors such as snow melt.

In March 2020, TEPCO reported that the amount of groundwater and rainwater flowing into reactor and turbine buildings was 106m^3/day; and the amount of water transferred from groundwater drains to reactor and turbine buildings was 7m^3/day.[18] This was in a week when there was no rainfall. In August 2020, TEPCO reported that the amount of groundwater and rainwater flowing into reactor and turbine buildings was 41m^3/day, and the amount transferred from groundwater drains to reactor and turbine buildings was 6m^3/day.[19]

During typhoon season, the variations in water entering the site and becoming contaminated can be dramatic. For example, Typhoon Hagibis in October 2019 led to a rise to over 650^3m/day. This volume of water is exceptional. It is clear that ongoing groundwater contamination will require TEPCO to continue to store and process water for the foreseeable future. As stated in our January 2019 report, "There are no prospects that TEPCO's current technology will reduce ongoing ground water contamination to zero as claimed by TEPCO in 2014. TEPCO is thus faced with the prospect of a relentless build up in contaminated water at the site over coming years."

As long as the molten corium fuel is exposed to the environment, groundwater contamination will continue. It is worth noting that the radioactivity of the 1.2 million tons of tank water is only a small fraction of the total radioactive inventory of what remains at the site. It is estimated, for example, that the radioactive cores of three reactors at Fukushima Daiichi contained 520PBq of strontium-90 before they melted down.[20] Between 1% and 3% of this was subsequently released into the Pacific Ocean – an enormous amount.[21] However, most strontium-90 remains in the molten cores at the site, an amount 17.3 million times more than would be released under the Japanese government's plans for the one million tons of contaminated water. This staggering amount of strontium must be prevented from entering the environment. However, it's clear that this is already occurring through groundwater contamination and TEPCO have no credible plan that will stop this in the coming years. Tritium and strontium-90 have half-lives (the time it takes radiation to decay by 50%) of 12.3 and 28.8 years respectively. This means that, for these radionuclides alone, the radiation risk will remain for 125 to 290 years (the risk period is generally considered to be ten half-lives). However, there are many other radionuclides with even longer half-lives present in the contaminated water. For example, iodine-129 has a half-life of 13 million years.



Failure of the Advanced Liquid Processing System (ALPS)

"Initial results from tests using contaminated sea water and outlet water from the cesium removal process have demonstrated that 62 radionuclides can be removed to achieve levels that satisfy the regulatory limits for discharge." -International Atomic Energy Agency (IAEA)[22]

In August 2018, it was disclosed that water processing in three ALPS systems at the Fukushima Daiichi site had failed to reduce levels of radioactivity, as had been claimed.[23] On 28 September 2018, TEPCO admitted that hundreds of thousands of tons of stored water contained higher concentrations of dangerous radioactive materials than levels permitted by the safety regulations for release into the ocean.[24] In 2020, TEPCO reported that 780,000 tons of water, or 72% of the total water in storage tanks, would undergo secondary processing.[25]

In 65,000 tons of treated water, the levels of strontium-90 are more than 100 times the regulatory standards, according to TEPCO. The levels are as high as 20,000 times the standards in some tanks. Strontium is one of the most hazardous radionuclides and must not enter the environment as it concentrates in plants, animals and humans. It is often referred to as a 'bone seeker' as it behaves like calcium and is deposited in the bones and bone marrow, resulting in a higher risk of leukaemia or blood cancer. TEPCO was clearly being dishonest in its claims that the ALPS processing technology would reduce radioactivity levels "to lower than the permissible level for discharge." [26] Although TEPCO admitted ALPS failure in 2018, a review of publicly available documentation shows that it knew as early as 2013 that the radioactivity levels in a proportion of ALPS-treated water was not being reduced to target levels.[27]

ALPS systems failure is almost entirely a result of flawed decision making and the wrong technology choices driven by short-term financial considerations. The disclosures confirm suspicions that TEPCO was not providing accurate results of the ALPS processing decontamination factors (DF) determining the efficiency of removal of radionuclides at Fukushima Daiichi.

In June 2018, consulting engineer John Large reviewed some of the public data provided by TEPCO for Greenpeace Japan. His initial analysis concluded that there were significant questions over the accuracy of TEPCO's information. Its 2016 data sheets reported that, after processing, the concentration of caesium-137 was 30Bq/l, a level which Large points out is "remarkably spot on the discharge limit to the marine environment."[28] How was it that TEPCO, which knew there were wide variations in the DF of processing systems, including ALPS, published data that did not reflect reality? And why did it take TEPCO so long to publicly admit something it had known for at least five years?

Poor technology choices and the failure of ALPS

In 2011, the American water separations company, Purolite, which has extensive global nuclear experience, together with Hitachi General Electric Nuclear Energy Ltd (HGNE), operated an early ALPS test facility at the Fukushima Daiichi site. The results were encouraging and according to Purolite demonstrated that it was possible to remove 62 radionuclides, with the exception of tritium.[29] However, rather than securing a contract for building and operating an ALPS based on Purolite ion exchange technology, the contracts were instead awarded to Toshiba, and eventually HGNE, while Purolite was excluded. This is significant. Purolite had decades of experience in water processing ion exchange, but Toshiba and HGNE had almost none. Purolite subsequently sought compensation through legal action, accusing HGNE of violation of a non-disclosure agreement by providing trade secret design information from Purolite to a third party without permission. Moreover, it accused HGNE of using this information in the design and operation of the high-performance ALPS.

Evidence presented in subsequent lawsuits brought by Purolite against HGNE highlighted how the failure of TEPCO to apply superior technology and experience has had a negative effect on the performance of ALPS. Purolite states that its Purolite Core Technology successfully achieved non-detectable (ND) levels for 62 of the 63 radionuclides during its 2011 test operations, which was in accordance with TEPCO's specifications.[30] The ND target was specified by TEPCO, and as late as 2014 it was continuing to state that the "new high-performance water treatment system...(will) reduce strontium to non-detectable levels."[31]

With the subsequent failure of ALPS, the ND target was replaced with targets below Regulatory Limits. In practice, this means that a future release of processing water from Fukushima will contain levels of dangerous radionuclides that TEPCO originally had planned to remove. Even with secondary processing of water as planned, levels of contamination of such radionuclides as strontium-90 and iodine-129 will be far higher than the levels achieved by Purolite technology in 2011.

In a confidential presentation to the Tokyo Court in July 2017, Purolite stated that it was "indisputable that nobody other than Purolite had the technology that matched TEPCO's ND level standard. Indeed, this is precisely the reason Toshiba, HGNE, and other companies failed with later water treatment."[32]

The performance of Purolite's processing technology in meeting TEPCO's ND specification was independently confirmed in February 2012 by the Japan Atomic Energy Agency (JAEA).[33] The evidence shows that, as early as 2012, TEPCO had technology available to reduce concentrations of all 62 alpha, beta and gamma emitting radionuclides in the contaminated water (not including tritium). TEPCO's decision to contract with Toshiba, rather than continuing in partnership with Purolite, appears to have been a significant factor in the failure of ALPS, something that had concerned the company itself. In 2017, Purolite cited the opinion of TEPCO's Yamashita, who stated: "I (am) seriously concern(ed) if Toshiba group can continuously achieve ND next more than ten years (sic)".[34]

Purolite's evidence to the Tokyo District Court included details of their technology and expertise in water processing unknown to HGNE or Toshiba.[35] As detailed in our January 2019 report, these included critical issues of contact time for adsorbers and pH adjustments. Purolite's statement to the court included the following:

Adsorbers

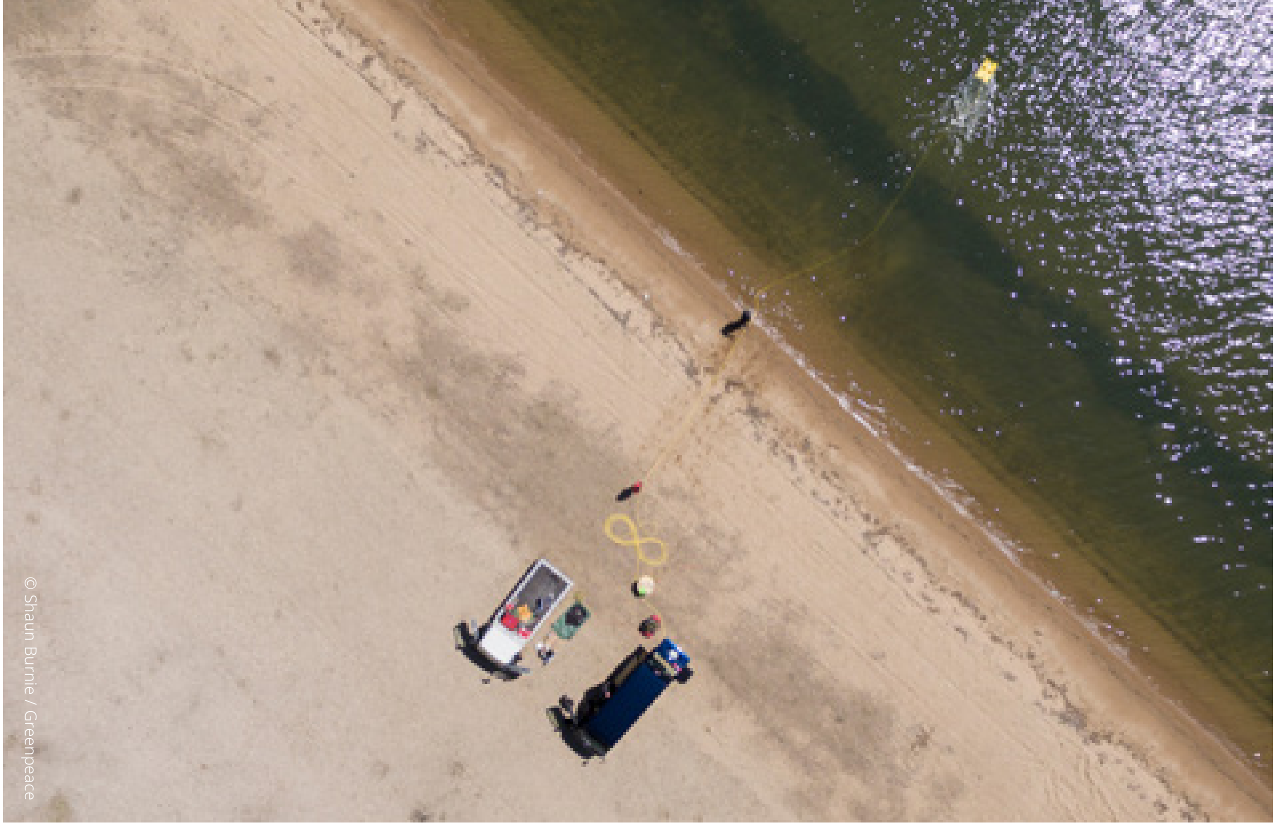
"The contact time, or the time during which the adsorbent is in contact with the contaminated water, is a value calculated by dividing adsorption capacity by the volume of contaminated water flowing into the adsorption towers (volume of contaminated water passing through the adsorbent per minute). During tests, the two values were adjusted to find a contact time that would enable the adsorbents to carry out adsorption most effectively. An adsorbent requiring a long contact time could not be put into practical use in machinery with a limited processing time, while if the contact time was too short, water would flow out without multi-nuclides being sufficiently adsorbed, and it would be impossible to evaluate the true potential of the adsorbent. Therefore, a crucial factor in the development of a highly responsive emergency purification system is to set the contact time when assessing adsorbents so that it is in equilibrium, and neither too short nor too long. Moreover, when calculating the optimum contact time, it is necessary to maintain the contact time when scaling up in size to actual machinery, and this is extremely important information when deriving actual machine specifications from tests."

pH adjustments in relation to water chemistry

"The design of a radionuclide removal process that incorporates multiple pH adjustments between its various stages had not been put into general practice in the industry. Such a process also differed from the methods employed in other cases of nuclear power plant meltdowns that have some similarity to the current case. Other cases of contaminated water treatment have tended to eliminate the step of pH adjustment altogether or have kept it to a minimum. This is because pH adjustment requires additional facilities and additional management of the process, and workers will need to take more care and be required to handle acidic and corrosive agents, and these factors have generally made it more likely for problems to occur. Furthermore, at Fukushima Daiichi NPS it was necessary to remove radionuclides from approximately 100,000 m^3 of cooling water kept in multiple storage tanks on site. Here the additional difficulty arose that this cooling water was a mix of seawater and freshwater, and contained the high concentrations of saline you would expect to find in seawater, thereby impeding the rate at which the radionuclides emitted from the reactor could be removed. For these reasons, this case differed from other meltdown cases, in which radionuclides were removed from freshwater."

Purolite evidence to the Tokyo District Court stated that it had, "succeeded in overturning common practice in the contaminated water treatment industry, by discovering that it was optimal to carry out multiple pH adjustments between stages when treating the contaminated water at Fukushima Daiichi NPS, and actually finding the most effective method of implementing this."

In ruling against Purolite's claim, the court concluded that there was insufficient evidence to find that the HGNE had used Purolite information to develop an effective adsorbent, and in the design of the adsorption tower arrays. The reality is that Hitachi and TEPCO did not build and operate an effective ALPS system, resulting in the failure to attain ND levels of contamination in all of the processed water, and the fact that 72% of existing tank water is required to undergo secondary ALPS processing. It is worth noting that representatives of Purolite made repeated offers to supply their water processing knowledge and technology to TEPCO or the Ministry of Economy Trade and Industry (METI). These offers pre-date the legal proceedings, but were also made during and subsequent to the court ruling. On each occasion the offer has been rejected.



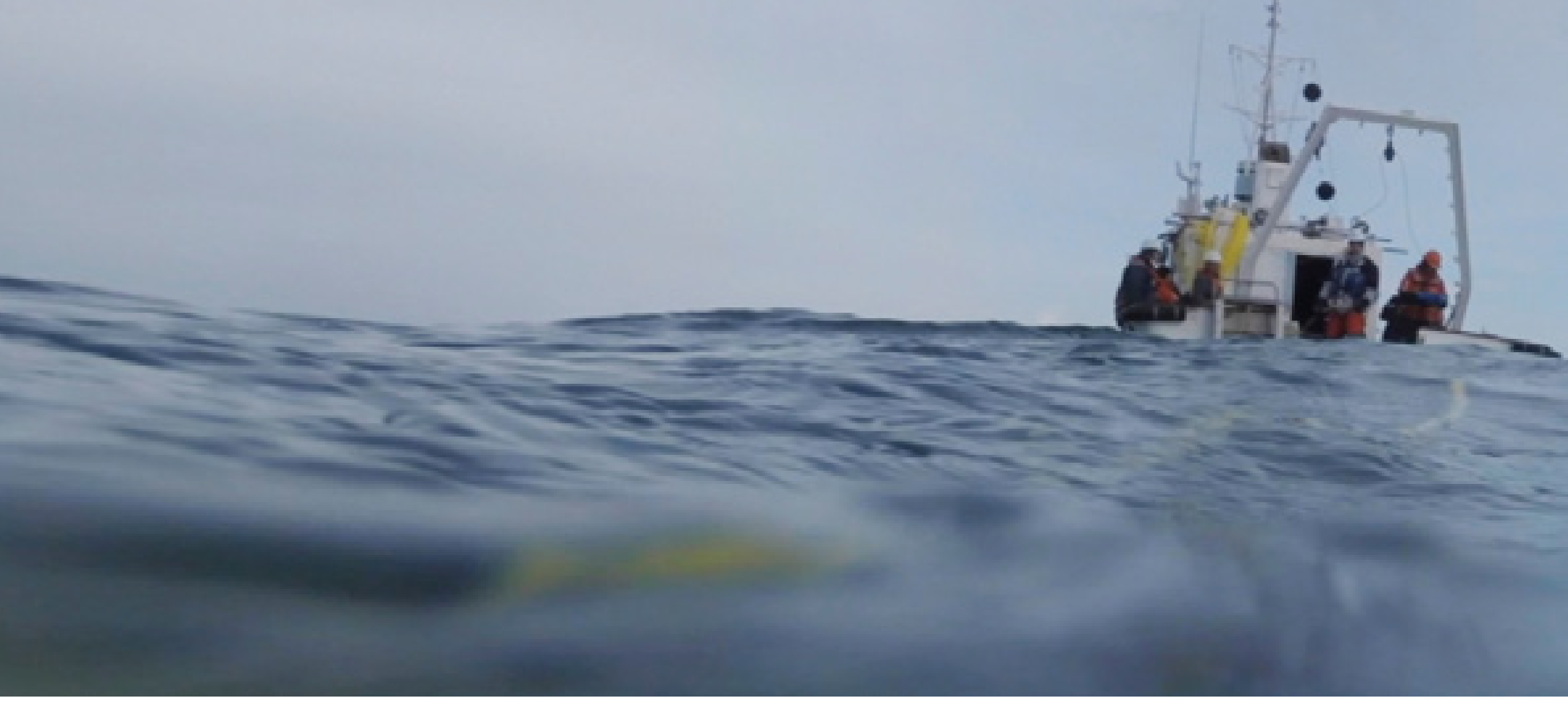
Secondary processing in ALPS 2020

In September 2020 TEPCO began a pilot test for the secondary processing of contaminated water.[36] This ALPS processing is intended to reduce the concentrations of radionuclides such as strontium-90 and iodine-129 to below regulatory limit levels. According to TEPCO, the test phase is to involve about 2,000 m^3 of water with a level 100 times or more above the regulatory concentration limit.[37]

A major question is how effective it will be given past failures. If the same failed technology as before is used, will it fail again? If it does, will the government consider discharging this water as well? There has been no independent verification of the radionuclides content of the tank water at Fukushima Daiichi and given the past record of cover-ups and lack of transparency, this is a grave concern.

In March 2020, TEPCO stated that the secondary treatment, “will be carried out to reduce the amount of radioactive substances released into the environment as much as possible.”[38] This is an admission of the failure of ALPS and a retreat by TEPCO from its earlier commitment to reduce concentrations of radioactivity in the contaminated water to below the detection limit (ND). As the Purolite CEO, Steve Brodie, warned in 2012, “Achieving non-detect levels on all 62 radionuclides is critical to local community, fishermen, farmers, neighboring countries and governmental bodies in order to safely discharge the cleaned up water to the ocean. If any of the 62 radionuclides are not reduced to non-detect levels, TEPCO may be forced to build even more storage tanks, which are exposed to rupture and spillage, until a satisfactory solution can be found.”[39]

The failure of ALPS is one reason the water crisis remains such a controversial issue in Fukushima, the rest of Japan and internationally. It remains to be seen whether the secondary processing of hundreds of thousands of tons of contaminated water will be successful, at least in terms of reducing concentrations of dangerous radionuclides to below regulatory limits. TEPCO long ago abandoned its commitment to minimise the radiological impact of any discharges by quietly dropping a commitment to reach Non-Detectable levels.



Strontium-90 and other hazards

As we have reported, the Japanese government and TEPCO are deliberately downplaying the radionuclides that will be discharged into the environment. These hazardous radionuclides include radioactive strontium, iodine, and plutonium.

As Ken Buessler of the Woods Hole Oceanographic Institute has reported recently,[40] these radioactive isotopes, "behave differently than tritium in the ocean and are more readily incorporated into marine biota or seafloor sediments. For example, the biological concentration factors in fish are up to 50,000 higher for carbon-14 than tritium.[41] Also, isotopes such as cobalt-60 are up to 300,000 times more likely to end up associated with seafloor sediments.[42] As a result, models of the behavior of tritium in the ocean, with tritium's rapid dispersion and dilution, cannot be used to assess the fate of these other potential contaminants. To assess the consequences of the tank releases, a full accounting after any secondary treatments of what isotopes are left in each tank is needed. This includes the volume, not just for the nine isotopes currently reported but for a larger suite of possible contaminants, such as plutonium."[43]

A deliberate decision by the Japanese government to discharge highly radioactive water from Fukushima must also be put in the overall context of there already having been enormous releases of radioactivity into the Pacific Ocean since March 2011. For example, releases of caesium-137 between May 2011 and December 2014 are equivalent to 500,000 years of discharges from the largest nuclear plant in Western Europe at Gravelines in France, where six reactors operate.[45] These discharges are only a small fraction of the radioactive inventory remaining at the site. It is estimated that the radioactive cores of three reactors at Fukushima Daiichi contained 520PBq of strontium-90 before they melted down. Between 1% and 3% of this was released into the Pacific Ocean.[46]

However, most strontium-90 remains in the molten cores at the site, an amount 17.3 million times more than would be released under the Japanese government's plans for the million tons of contaminated water. But it is already clear that some of this strontium-90 is entering the environment through groundwater coming onto the site and TEPCO has no credible plan to stop groundwater contamination in the coming years.

Carbon-14 in the contaminated water – an admission

Radioactive carbon, specifically carbon-14 (c-14), is one of the most significant radioactive materials produced during nuclear reactor operation. Since 2011, TEPCO and the Japanese government have predominantly focused on radioactive iodine, caesium, tritium and, to a much lesser extent, strontium, with regard to the contaminated water. The ALPS has been promoted as capable of removing 62 radionuclides, but the one radio isotope we were told would not be removed by ALPS was tritium and this would have to be discharged. However, this is not the whole story.

There are two major sources of carbon-14 in irradiated or spent nuclear fuel: neutron activation of nitrogen (contained in the fuel as an impurity and/or additive); and oxygen (contained in the fuel as UO2). Carbon-14 is retained in spent fuel and if this is chemically reprocessed it is released in both gaseous and liquid form. The biggest sources of carbon-14 entering the global environment are reprocessing operations, largely at La Hague in France and at Sellafield in the UK. Although not a reprocessing plant, the 2011 triple reactor meltdown at Fukushima Daiichi led to both atmospheric and liquid carbon-14 releases into the environment of Fukushima and more widely in Japan.

Carbon-14 is incorporated into all living matter to varying degrees of concentration.[47] The International Atomic Energy Agency (IAEA) reports that the human body metabolises carbon-14 in the same way as ordinary carbon and it enters many body tissues. The biological half-life (time required for the body to eliminate 50%) of carbon-14 is approximately 40 days, and most of the accumulation in the body comes from ingestion of contaminated food rather than from respiration. It is easily concentrated in the food chain – studies have shown concentration factors of 5,000 for fish and molluscs, and 2,000 for soil sediments.[48]

Because of its long environmental half-life of 5,730 years, carbon-14 is a major contributor to global human collective dose over time, and doses in an exposed population can be converted into the corresponding number of health effects.[49] It is integrated in cellular components, such as proteins and nucleic acids, particularly in cellular DNA.[50] The resulting DNA damage may lead to cell death or potentially inheritable mutations.[51]

The ALPS at Fukushima Daiichi was not designed to remove carbon-14 and did not do so. If the Japanese government decides to discharge the contaminated water into the Pacific Ocean, all the carbon-14 in the tanks will be released into the environment. TEPCO, METI and other agencies of the Japanese government have failed to explain this and have very rarely mentioned carbon-14, emphasising that the remaining isotope was tritium, which was of no consequence. As recently as June 2020, the Japanese Ministry of Foreign Affairs is quoted as explaining to the United Nations' Human Rights Special Rapporteur: "After most of the radionuclides except tritium are removed in this purification system (ALPS), the water is safely stored in the tanks as ALPS treated water...Therefore ALPS treated water stored in the tanks is not contaminated water."[52]

On 27 August 2020, TEPCO published a document that acknowledged that the presence of carbon-14 was a significant contributor to the overall beta radiation measurements of contaminated tank water.[53] This was followed by a further document on 10 September 2020.[54] TEPCO does not explain why it has taken so many years to acknowledge the scale of the carbon-14 problem. In the August document, TEPCO acknowledges that "...a large deviation (that) has been found between the sum of ratios of concentrations required by law from ALPS outlet assessments and the sum of concentrations required by law calculated from the results of tank sampling."[55] In other words, the total beta radiation amount was larger than the sum of all the beta isotopes they had measured until that point. It then confirms that carbon-14 is the cause of this deviation.

The September document explains that the secondary ALPS test, scheduled for October 2020, would be followed by measurement of the processed water for "the 62 nuclides targeted for removal in addition to radioactive carbon (C-14) and tritium (H-3)". As far as we are aware, this is the first time that TEPCO have confirmed plans for specific carbon-14 measuring as part of the secondary ALPS. In one of the few previous references to carbon-14, it reported in 2014 that it was non-detectable in ALPS water before and after processing.[56] In reality, this was not based on any actual measuring for C-14 but instead an estimate based on caesium concentrations.

Given the long-term hazard of radioactive carbon-14, and that it is nearly ten years since the Fukushima Daiichi disaster occurred, this is yet another serious failure by TEPCO and the Japanese government. The discharge of radioactive carbon-14 will inevitably lead to its accumulation in marine life along the coast of Fukushima, more widely across Japan, and in the waters off the Korean peninsula and China. This will result in increased human consumption. Additionally, its long half-life means global distribution through ocean currents over time.

In November 2019, METI, when seeking to represent the low risk from tritium releases, cited carbon-14 as one of the radioactive isotopes that has a greater impact on "living organisms".[57] Though not exactly clear on what they meant, in the table entitled "Comparison of impact of tritium and well-known radioactive nuclides on living organisms", METI gave tritium a value of 1, compared with C-14 at 32. This appears to suggest that C-14 is 32 times more hazardous to life than tritium. Greenpeace agrees with METI that carbon-14 is a more significant threat to human health than tritium.

It is possible to remove carbon-14 from liquid waste.[58] However, it seems that TEPCO and the Japanese government chose not to consider developing options for this. If the contaminated water is discharged and all of the carbon-14 is released into the environment, the repercussions will last tens of thousands of years.

Flaws in tritium risk analysis

TEPCO continues to misrepresent and selectively ignore basic scientific facts on radioactive tritium. In its publications, made available in Japanese and English, it explains that tritium mostly exists as hydrogen in water molecules.[59] While the METI subcommittee acknowledges that a portion of tritium also becomes organically bound tritium (OBT), TEPCO's information is intended to give the impression that it is not possible for tritium in any form to enter the human body and have any radiological effect.

In seeking to justify plans for the release of contaminated processed water, in September 2019 the Japanese government misleadingly states, "It has not been found that tritium concentrates in humans and other particular living organisms, as tritiated water has similar properties as water."[60]

The government's Ministry of the Environment omitted any reference to OBT. After intervention by citizens' groups, including on the issue of OBT, the report of the Subcommittee on Handling of the ALPS Treated Water, tasked with assessing the options for managing the contaminated water, conceded that, "Tritium releases weak beta rays only and may impact the body through internal exposure." It also acknowledged that, "Of the tritiated water that enters the body, about 5% to 6% is converted into OBT, with the value taking into account the effect of the conversion ... The half-life of OBT in organisms comes in two forms: 40 days and about one year ... Considering this, the impact of the OBT is two to five times as large compared to tritiated water."[61]

However, the Subcommittee appears not to have looked into the impact of OBT in marine discharges. It reported in February 2020 that, "For discharge into the sea, concentration of radionuclides which are below their lower detection limit are assumed to be their detection limit value, and zero. In the case of vapor release, the effects of organically bound tritium (OBT) which is converted from tritiated water (HTO) are also considered."[62]

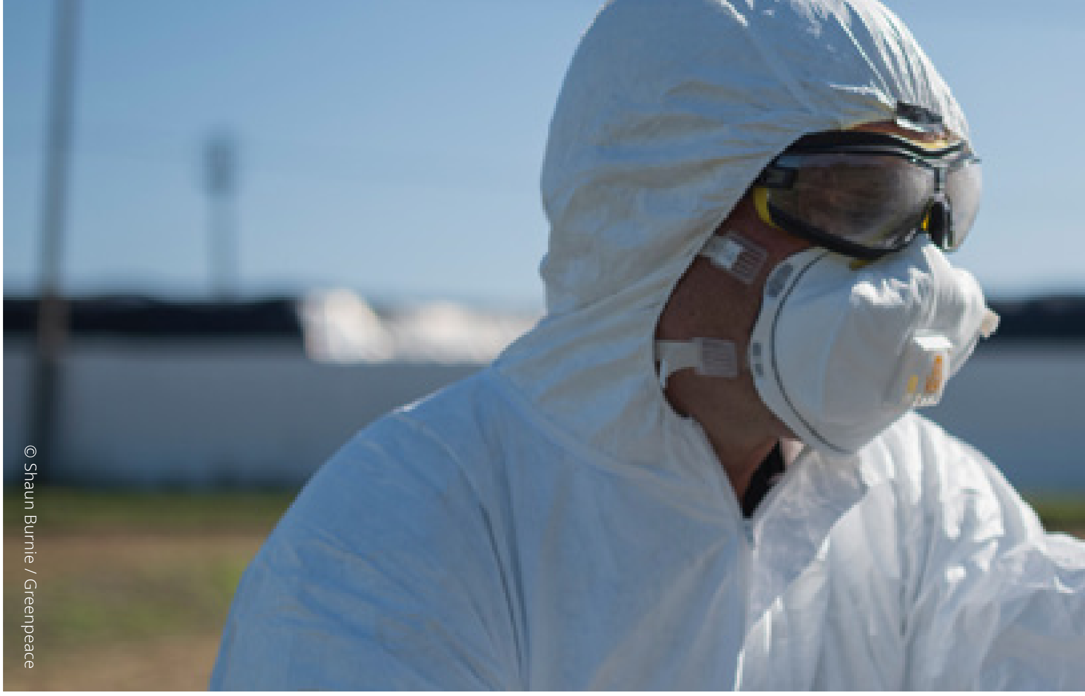
The Japanese government and TEPCO are deliberately misrepresenting the hazards from tritium. By failing to explain the role of OBT, they are not providing accurate scientific data on the potential impacts of any future releases of contaminated water. Greenpeace has consulted Dr Ian Fairlie, an expert on radiation in the environment, and he has concluded, "The problem is that the ICRP/IAEA [International Commission on Radiological Protection/International Atomic Energy Agency] dose models are for single discharges, but when multiple discharges occur the levels of OBT build up gradually."[63]

However, discharges of contaminated water from Fukushima Daiichi will take place over decades. Therefore, the Japanese government and TEPCO are underestimating OBT doses from consumption of contaminated seafoods.[64]

Fairlie further explains:

"Following HTO [tritiated water] intake, the current ICRP model (1989) assumes 100% is absorbed and enters the blood. It assumes a turnover half-life of 10 days for HTO. It also assumes that 5% of HTO administered is bound as OBT, and that OBT doses from HTO administration may be safely neglected. Animal studies are informative and reveal that doses from OBT must be considered. Commerford et al (1982) found, after a transient HTO exposure to mice, that all the remaining tritium was bound to DNA and histone eight weeks after exposure.[65]

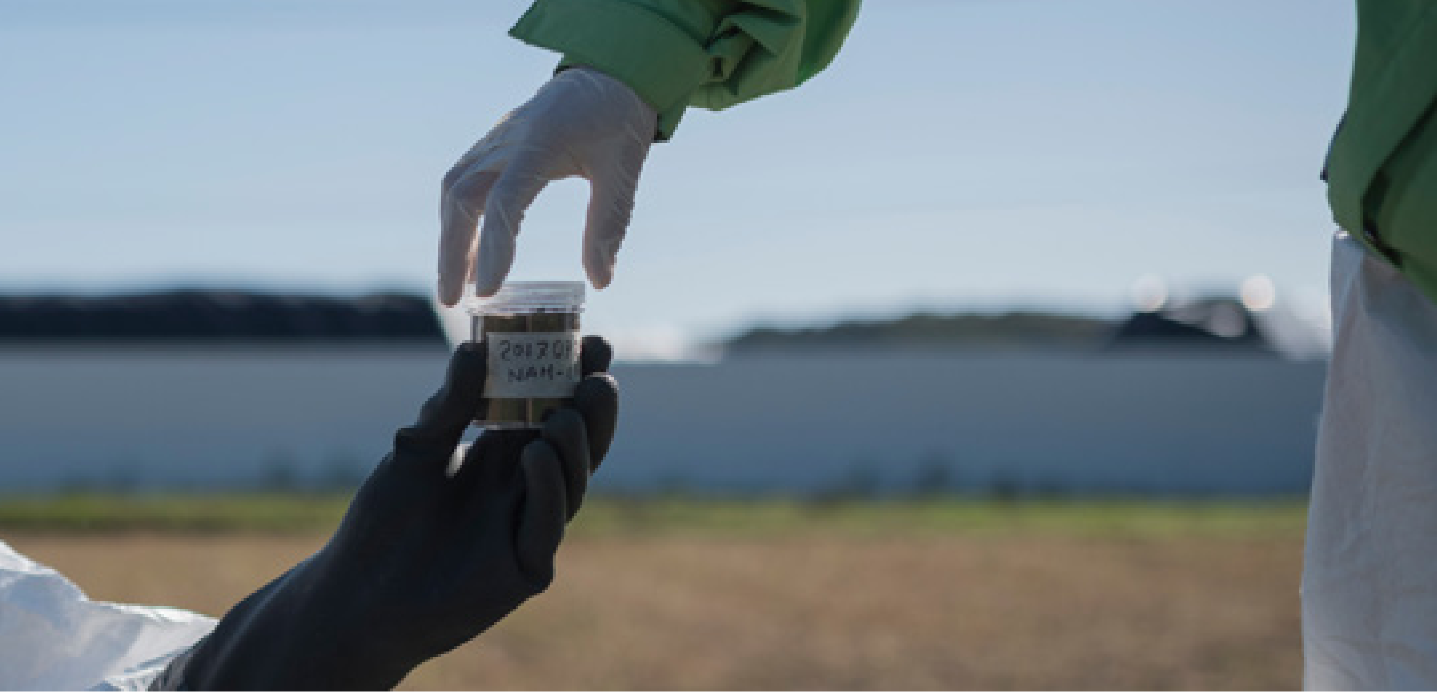
"Although the amounts were small compared to HTO, cell nucleoproteins were much longer-lived: the authors concluded that doses from them would exceed HTO doses. In addition, Trivedi et al (1997) estimated that an acute HTO administration in humans results in the range 3% to 9% being bound as OBT, not the 5% assumed by the ICRP. The problem is that the ICRP biokinetic



model ignores chronic exposures to tritium. These are important in the case of those living downwind from facilities which discharge tritium 24 hours a day. The ICRP considers chronic exposures to be merely repeats of one acute exposure. That is, in each case, the main dose from HTO and none from OBT and the HTO and OBT being excreted before the next acute exposure. But this is incorrect: animal studies reveal that after chronic exposures to HTO most of the dose come from OBT. For example, Commerford, Carsten and Cronkite (1977) found most tritium doses came from the OBT component, two to three days after the cessation of a lengthy chronic HTO administration to mice. Rodgers (1992) concluded that because OBT was cleared much more slowly than tissue water tritium, OBT was the principal determinant in estimated radiation doses to mice following chronic exposure.[68]

"In fact, chronic HTO administrations result in OBT concentrations increasing to higher levels, depending on how long the administration lasts. In situations of chronic exposures over a few months or so, research nearly five decades ago reported that there was a theoretical maximum to T-labelling of organic molecules by HTO due to the fixed percentage (~30%) of exchangeable H bonds in the body.[69] There is some evidence to support this: Rodgers (1992) fed mice tritiated water to establish a steady state of T turnover: OBT levels rose to 22% of body HTO levels after 56 days. However it is unclear what would have happened had the experiment continued. Much evidence suggests that OBT levels would slowly continue to increase as tritium continues to be taken up by metabolic reactions. Eventually OBT levels, because of their very long half-lives, would equilibrate with body HTO levels. Most important are the studies of exposures from naturally-occurring tritium which indicate OBT/HTO ratios of 1. Essentially, there is a disjunction between the evidence from animal experiments and the evidence from background tritium levels/environmental studies. This may be due to the limited time lengths of existing biokinetic experiments. These experiments may need to continue for years due to the long half-life of OBT in humans, which could be many years."[70]

Dr David Boilley, of the radiation research laboratory ACRO at Caen in France, sees the approach of the Japanese government and TEPCO as problematic. He says that for "chronic discharges into the sea, it is generally assumed that the ratio of radioactive hydrogen to the total hydrogen is the same in water and organic bodies (the same hypothesis as for C-14)... I don't know how the



METI group did its calculation. No detail is given...Bioaccumulation of tritium in organic matter was highly debated in France because some marine animals had higher concentration than expected[71]...If the (government) want to fight against 'reputational damages', they should detail their calculations."[72]
The misreporting of organically bound tritium suggests that the Japanese government is deliberately seeking to reduce opposition to any planned discharges from the local fishing communities of Fukushima, other parts of Japan and countries such as South Korea.

Research published in December 2019, showed that tritium is preserved as organically bound forms in sedimentary reservoirs for decades.[73] The results, published in the scientific journal *Nature*, showed, "direct evidence of tritium preservation as OBT in sedimentary reservoirs over long periods of time, an important finding as this, while hypothesized, has never been demonstrated before to our knowledge." The authors report that, "While part of OBT (<30%) is easily exchangeable with water molecules in the surrounding environment, most OBT is sequestered long term. Its persistence within Organic Matter (OM) mainly depends on biodegradation rates of involved organic compounds. In soils and river systems, biodegradation processes affecting particulate OBT are expected to produce dissolved OBT and subsequently free mobile hydrogen that can rapidly oxidize towards tritiated water molecules. According to biogeochemical equilibrium describing most natural environmental systems, concentrations of free and bound forms of tritium are expected to be similar and therefore, ratios of OBT/HTO would be close to unity. Nevertheless, any perturbation due to artificial inputs of tritium into the environment can alter this equilibrium since water masses are recycled faster than OM." The authors conclude that, "the current consensual explanation for OBT/HTO disequilibrium is that tritium integrated into the OM would persist for the long term while the free forms rapidly exchange with the surrounding environment."[74]

And in conclusion, Eyrolle, F et al, states, "Our work raises immediate concerns regarding post-accidental management of tritium emissions with direct application to the case of Fukushima (Japan). It also provides additional key knowledge for the future management of tritium releases from nuclear industries."[75] There can be no justification for the failure of the Japanese government and TEPCO to fully explain the potential impacts of radioactive tritium discharges into the environment.

Failure to address the tritium problem

The failure of ALPS is compounded by the decision not to develop available technology to remove radioactive tritium from the processed water. As was explained in our January 2019 report, TEPCO had the option to develop tritium removal technology. Instead, the company and Japanese government agencies chose to disregard technology proposed by international nuclear companies such as Kurion, as well as the US Department of Energy. Kurion told the Japanese government that its Modular Detritiation System (MDSTM) “could remove the tritium from 800,000 cubic meters of water so that only about a cubic meter of the radioactive material remained.”[76] The estimated timeframe was five to eight years.

On 19 April 2016, the Japanese government’s Committee Water Task Force concluded that none of the tritium removal technologies could be applied at the Fukushima Daiichi site.[77] This decision was not based on the lack of suitable technology, but on the enormous financial implications. The Japanese government continues to deceive by saying that it is not possible to remove tritium, and this was what led the committee to conclude that environmental release to the Pacific would be the best way to treat low-tritium-concentration water.[78] As Gaetan Bonhomme, Kurion chief technical officer said at the time, "Some people will say that's expensive, but compared to what? I'd be very interested to talk to someone who says you should release this water, and discuss the costs of that...How would you do it? What would be the impact? And how would you compensate people who might be affected.”[79]

There is no doubt that the costs of processing the water would be high. According to Kurion, it would cost US$1bn to set up, plus several hundred million dollars a year to operate.[80] Cost estimates for the technology proposed by US Department of Energy PPNL are even higher at US$60 to US$180 per litre, which would be US$50bn to US$180 bn.[81]

The reality is that the Fukushima Daiichi disaster is going to cost hundreds of billions of dollars over the coming years. In March 2019, the Japan Center for Economic Research (JCER) released a revised cost estimate for the disaster, including for water storage. Total costs were estimated to range between 35 trillion yen and 81 trillion yen (US$310bn -720bn).[82] The costs of retaining the water on site and with no discharge to the Pacific were estimated at 51 trillion yen or US$480bn. This is based on a cost of 20 million yen (US$179,000) per cubic ton, which is close to the maximum cost for the US Department of Energy technology. It’s not hard to see why the Japanese government would prefer discharge when costs have been estimated at 300 billion yen (US$2.7 bn) to be paid over 40 years.

The government and TEPCO had set a target of solving the water crisis at the plant by 2020. That was never credible. Even the reprocessing of all contaminated water will take an estimated five to six years, and questions remain about its efficacy. Volumes of contaminated water will continue to increase in the coming years. Storage in tanks over the medium and even long term, with parallel development of processing technology, is the only viable option.

Long-term storage as an alternative to discharge

The Japanese government's main justification for proposing to discharge the contaminated water into the environment is that there is no option available for long term storage. The METI-appointed Subcommittee on Handling of the ALPS Treated Water appears to have given greater consideration to this issue than any other official body in Japan.[83] Their 2020 report, which is supposed to provide the basis for government decision making, makes clear that there are storage options available, albeit options that are problematic and time consuming. However, all of the proposed 'solutions' to the contaminated water crisis have multiple hazards and risks.

A careful reading of the evidence leads Greenpeace to conclude that the Japanese government's own expert panel shows that long term storage is possible, would reduce the amount of tritium hazard (through decay), and would be the least environmentally damaging option.

The government's subcommittee reported in 2020 that, "even with the additional tanks, according to the current tank construction plan, which plans to install more tanks with a total capacity of about 1.37 million m^3 before the end of 2020, the tanks are expected to be full around summer 2022, and additional space for installing more tanks than currently planned is restrained."[84]

After considering the option of building larger capacity tanks on the site, the subcommittee concluded that as long as they were built within the existing site, they would "not provide a significantly greater storage capacity compared with the standard tanks".[85] However, in two specific options – continued storage on the Fukushima site and off-site – the subcommittee presents evidence that shows there are alternatives to environmental discharge.

The critical section of their analysis concerns securing additional land outside the boundary of the Fukushima Daiichi site. As Greenpeace and others have noted, the two districts of Futaba and Okuma have areas of high radiation contamination and are largely depopulated. Two large interim nuclear waste storage sites have been under construction during recent years, and are the chosen locations for the millions of tons of contaminated soil removed during the decontamination programme that has lasted almost a decade.

In its review of off-site options, the subcommittee considers pipelines and vehicle transfer, as well as regulatory requirements. It states that if the contaminated water was to be transferred off-site, "legally compliant transfer facilities would be required and it would be necessary to obtain understanding from municipalities on transfer routes."[86] In terms of regulation, it states that, "as the storage of the ALPS-treated water means the handling of radioactive material", it would be necessary to conform to the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors (the Reactor Regulation Act), including the implementation of radiation sickness prevention measures, safety inspection and physical protection inspections. Installation of new radioactive material storage facilities will require proper equipment, much complex coordination and an approval process, which will take considerable time.[87]

In Greenpeace's analysis, the subcommittee has correctly identified what would be required, and also admits these are effective options. The fact that protective measures would be necessary underscores that the ALPS-treated water is hazardous, despite TEPCO and the Japanese government suggesting it is 'just tritium'.

The option of securing land next to the interim storage facilities in Okuma and Futaba was considered by the subcommittee. Under an agreement with the host communities, Fukushima Prefecture and the central government, a final site for the permanent disposal of the largely soil-based nuclear waste is to be secured outside Fukushima Prefecture within 30 years – by around 2050. The subcommittee notes that, "the Mid-and-Long-Term Roadmap, the decommissioning of the Fukushima Daiichi NPS, aims to complete within 30 to 40 years after the achievement of the cold shutdown status in December 2011. Disposal of the ALPS treated water is equivalent to 'the disposal of the material contaminated by nuclear fuel materials' stipulated as part of the decommissioning in the Reactor Regulation Act. The disposal of the ALPS treated water must be completed as a part of the decommissioning works when the decommissioning itself is completed with an important premise that Fukushima reconstruction and the decommissioning should be two major principles. Hence, it should be assumed that the continuation of storage will end at the completion of the decommissioning."[88]

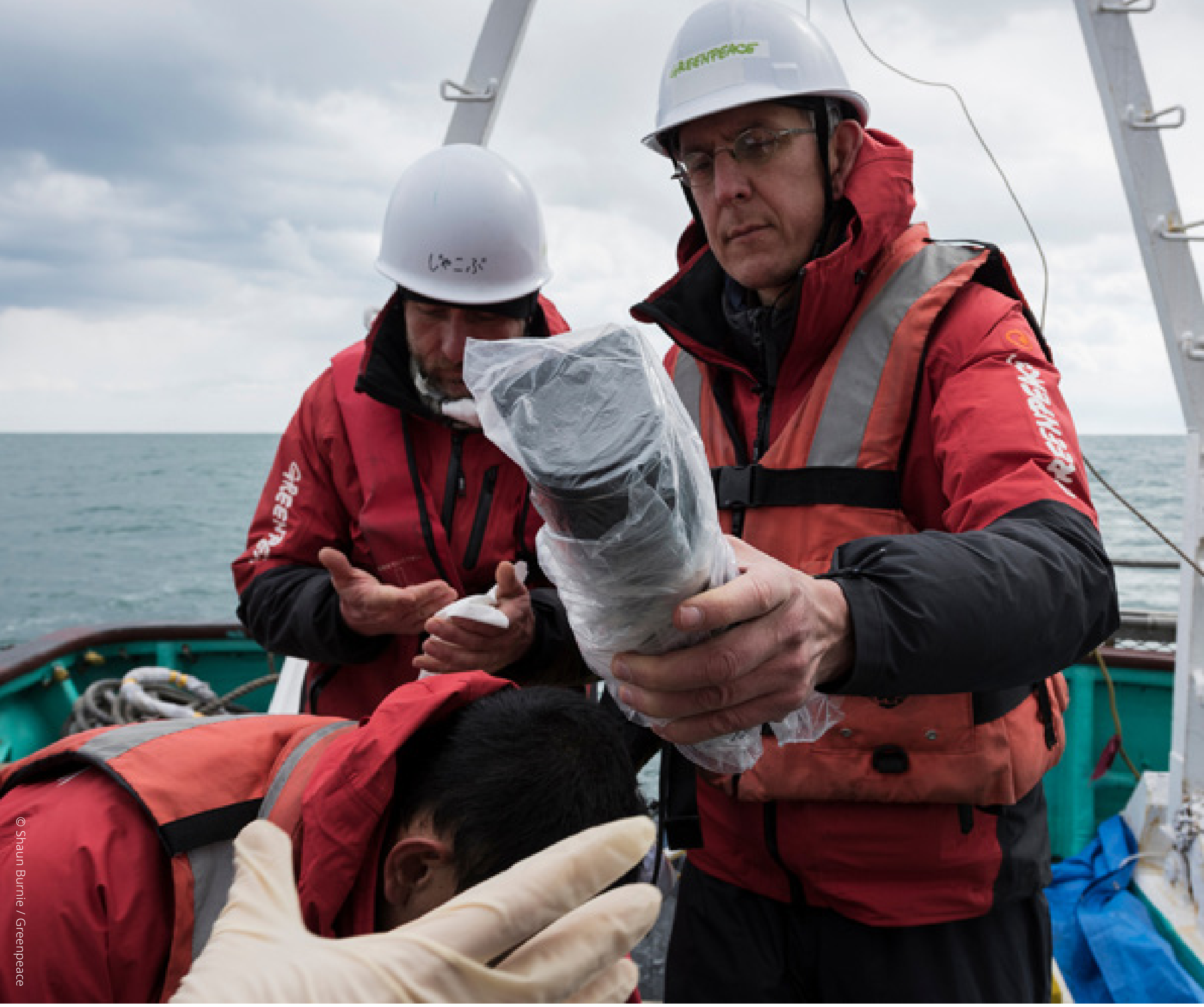
The reality is that the 'Mid-and-Long-Term Roadmap' is not credible and will be revised many times in the coming years and decades. This is obvious, although it cannot be stated by any of the official bodies. The millions of tons of nuclear waste soil that has been transported to Okuma and Futaba is unlikely to ever be removed, and certainly not within 30 years. There is no other prefecture in Japan that will accept the Fukushima Daiichi waste. To propose the long term storage of contaminated water would be to directly undermine the Japanese government and TEPCO narrative that all the nuclear waste generated by the disaster, including hundreds of tons of molten corium fuel and millions of tons of contaminated soil, will be removed by mid-century. On the eve of the tenth anniversary of the disaster, it is a government priority to maintain the multi-trillion yen myth at the centre of official propaganda, that effective and complete decommissioning and decontamination is possible at Fukushima Daiichi within the next few decades.

The subcommittee states: "To ensure the storage of the soil and other waste, including the soil removed from the zone designated for reconstruction and recovery, it is necessary to continue land acquisition and facility preparation work. Accordingly, it is deemed difficult to expand the area of the Fukushima Daiichi NPS site by using the land located outside the NPS for purposes other than intermediate storage, as this land has been allocated for the intermediate storage facility."[89]

There is no technical, engineering or legal barrier to securing storage space for ALPS-treated contaminated water. It is a matter of political will. But the decision by the government to dismiss the storage option is based on expediency – the least expensive option is to discharge into the Pacific Ocean.

Greenpeace agrees with the subcommittee that securing additional storage would take "a substantial amount of coordination and time would be needed until implementation to acquire the understanding from local municipalities and others, to decide upon where storage facilities might be built, and to acquire an approval for radioactive waste storage facilities."[90] However, the subcommittee then undermines its own reasoning when it confirms that additional time would reduce the radiological hazard of the ALPS-treated water, at least in terms of tritium. (see below)

By ruling out the off-site option, the subcommittee then returns to the option of continued storage on the Fukushima Daiichi site including the availability of additional space. "According to TEPCO, vacant land may become available on the site premises due to improved efficiency in the stored-water



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tank area (through utilisation of the space where flanged tanks used to be built) and progress in waste disposal efforts and other works. However, the ALPS treated water storage tanks and temporary storage facilities for spent fuel and fuel debris, as well as other facilities necessary for use in the decommissioning project will be required as decommissioning proceeds, including analysis facilities for various samples, fuel debris retrieval material and equipment storage facilities, fuel debris retrieval mock-up facilities, fuel debris retrieval training facilities and waste recycling facilities."[91]

The fundamental problem is the premise of TEPCO, and therefore the subcommittee and ultimately the Japanese government, that the current Mid- and Long-Term Roadmap will mean that areas currently designated, for example for the storage of up to 1,100 tons of molten corium reactor fuel, will be required in the coming decades. As Greenpeace has detailed elsewhere [92] there is no precedent for what TEPCO is attempting to do. The current timetable for removal of corium debris starting in 2021 and being completed by 2031 lacks all credibility and the fuel may not be entirely removed.[93] Thus, land on the existing Fukushima Daiichi site is available for additional storage tanks and is likely to remain so for decades or longer.

A clear case for pressing the pause button

The argument for delay is made explicit in the subcommittee report. Table 4 shows the time required for the disposal of the ALPS-treated water to the year of completion, according to the starting date and annual volume of disposal.[94]

Disposal amount / Start year of disposal	22TBq/year*1	50TBq/year	100TBq/year	Maximum storage volume*2
2020*3	33 years (2052)	19 years (2038)	10 years (2029)	About 1.30million m^3
2025	33 years (2053)	33 years (2041)	9 years (2033)	About 1.47million m^3
2030	33 years (2054)	33 years (2043)	8 years (2037)	About 1.65million m^3
2035	33 years (2055)	33 years (2046)	7 years (2041)	About 1.83million m^3

*1 Duration when yearly disposed volume is the same as the release control standard value for Fukushima Daiichi NPS before the accident.

*2 Current tank construction plan considers building additional tanks up to 1.37 million m3 of capacity by the end of 2020.

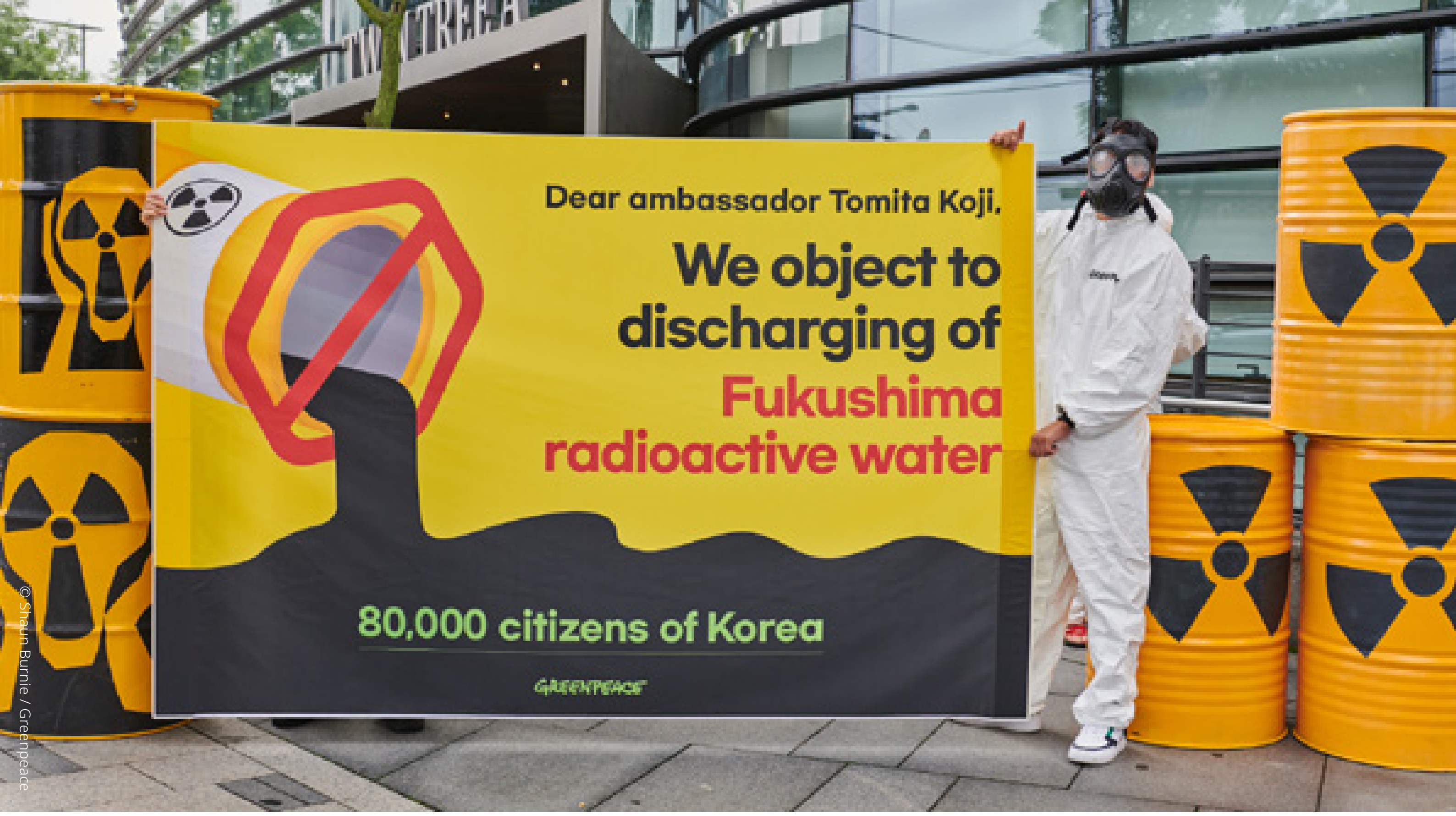
* Since there is no possibility to commence the disposal in 2020, the row is presented as a reference case to show the relationship between annual disposal volume and duration.

It's important to note that discharge will not begin in 2020 – this is used as a reference date. The key issue highlighted by the table is that if a maximum of 22TBq per annum was discharged from 2035, the discharges would be completed in 2055, compared with 2052 if the same amount was discharged each year from 2020.

The principal reason for the 14 additional years of discharge if they were to begin in 2020, is that waiting until 2035 (fifteen years) is greater than one half-life of tritium (12.3 years), so the total radiological inventory would be less than half of today's amount due to decay. The known hazards of tritium mean this is one more argument for deferring any discharge decision.

It's important to emphasise that a delaying decision would make little or no difference to the inventory in terms of the longer-lived radionuclides, including strontium-90 (half-life of 30 years), plutonium-239 (half-life of 24,110 years), or iodine-129 (half-life of 15.7 million years). But as the Japanese government talks exclusively about tritium water, as if the other radionuclides did not exist, Table 4 makes a clear and coherent case for delaying any decision for at least 15 years. It also aligns with the need for substantial additional time to negotiate options for off-site storage as the inevitable delays and changes to the decommissioning plan emerge.

Unfortunately, the subcommittee evades the obvious recommendation to delay any decision by stating that, "the Government of Japan should take the responsibility of determining the appropriate timing for initiating the disposal and the duration of the disposal taking into consideration the various factors related to the timing, the influence on reputation as well as the opinions of the parties concerned."[95]



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Human rights under threat

"We call on the government of Japan to give proper space and opportunity for consultations on the disposal of nuclear waste that will likely affect people and peoples both inside and outside of Japan. We further call on the Government of Japan to respect the right of indigenous peoples to free prior and informed consent and to respect their right to assemble and associate to form such a consent." United Nations Human Rights Special Rapporteurs, 9 June 2020.[96]

As with many other issues arising from the Fukushima Daiichi nuclear disaster, the United Nations Office of the High Commission for Human Rights (UNOHCR) Special Rapporteurs (SRs) have expressed the opinion that the contaminated water is a human rights issue.

On 9 June 2020, the four UN SRs urged the Japanese government to, "delay any decision on the ocean-dumping of nuclear waste water from the reactors at Fukushima Daiichi until after the COVID-19 crisis has passed and proper international consultations can be held."[97] They had already explained their concerns in a detailed submission to the Japanese government in April 2020.[98] "While TEPCO plans to conduct secondary treatment of large amounts of the ALPS-treated water prior to any discharge, significant amounts of radioactive materials will remain, including strontium. The disposal of contaminated water from the Fukushima nuclear disaster into the ocean or air will jeopardize a multitude of human rights and the livelihoods of a large number of communities, including indigenous communities who are heavily dependent on fishing for income and subsistence...The decision to dispose of contaminated wastewater into the ocean would also seriously affect the human rights and livelihoods of local fishermen, who have invested enormous efforts into rebuilding their industry after the nuclear plant disaster."[99]

The response of the Japanese government was to ignore the basic principles of human rights raised by their intervention. Instead the government misrepresents the radiological content of ALPS-processed contaminated water, and goes as far as to say that, “After most of the radionuclides except tritium are removed in this purification system (ALPS), the water is safely stored in the tanks as ALPS treated water...Therefore ALPS treated water stored in the tanks is not contaminated water.”[100]

It’s not clear what the government hopes to achieve by this false claim. Obviously, the water currently stored in tanks at Fukushima Daiichi, including the vast majority of the water that has undergone ALPS processing, remains contaminated with radioactivity. The closest the government came to admitting the issue has a social dimension was when it stated that, “Currently, towards determining its basic policy on the handling of ALPS treated water, the GoJ continues to listen to opinions from the parties concerned including local residents considering the report of the Subcommittee on Handling of the ALPS Treated Water.” The government may listen but it does not mean it will take into account what it hears. Masato Kino, METI’s director for Fukushima Daiichi decommissioning, said in March, “We’ll consult with local people, rather than getting the consent from them, to take action”.[101]

The communities and citizens of Fukushima Prefecture have made their position clear to the government. Starting in March 2020, resolutions have been passed by municipalities expressing their concerns and opposition to the release of the contaminated water. The Citizens' Alliance ‘Stop Polluting the Ocean’ has reported that written statements have been adopted by 41 local councils representing 59 local authorities as of 3 July 2020. These include clear opposition to any discharge, and all reflect the position that the proposals of the METI subcommittee cannot be immediately accepted. As the Alliance explained, “It is notable that such opposition has been emerging from every corner of Fukushima Prefecture, including inland areas. Koganei city council (within the Tokyo metropolis) has adopted a resolution opposing oceanic discharge and calling for land-based storage. On 23 June 2020, at the ordinary general meeting of the National Federation of Fisheries Co-operative Associations, and on 26 June 2020 at the ordinary general meeting of the Fukushima Prefectural Federation of Fisheries Co-operative Associations, special resolutions to ‘firmly oppose oceanic discharge’ as a method for disposing of treated water were unanimously approved.”[102]

A statement from Ishikawa town, said, “Victims who have been severely damaged by the nuclear accident should not be overwhelmed by the release of contaminated water into the ocean. This will fundamentally overturn the efforts and future prospects of producers who have worked to ensure the safety of agricultural, livestock and marine products produced in Fukushima Prefecture and overcome the damage caused by rumors.”[103] The town’s submission to Prime Minister Abe concluded with: “We strongly desire research and development of treatment methods including tritium separation treatment in addition to long-term storage in the process leading to the end of decommissioning treatment, and we oppose the release of contaminated treated water containing tritium into the ocean.”[104]

In one of his last duties as a UN Special Rapporteur, Baskut Tuncak[105] made clear that, “The communities of Fukushima, so devastated by the tragic events of March 11 2011, have in recent weeks expressed their concerns and opposition to the discharge of the contaminated water into their environment. It is their human right to an environment that allows for living a life in dignity, to enjoy their culture, and to not be exposed deliberately to additional radioactive contamination. Those rights should be fully respected and not be disregarded by the government in Tokyo.[106]

Conclusion

Two years after our first report on the Fukushima water crisis, the Japanese government has decided that it will discharge the radioactive water into the Pacific Ocean. According to the plan, discharges will begin in late 2022 or 2023, and last until the mid-2050s.

The Japanese government and TEPCO have created a myth around the million plus tons of contaminated water – that by 2022 there will be no further space for storage; that radioactive tritium is the only radionuclide in the water and that it is harmless; that the water is not contaminated; and that there are no alternatives to discharge.

This report, as with our earlier 2019 analysis, exposes this narrative as false. It has been created for both financial and political reasons. Discharge is the cheapest option and it furthers the objective of the government to create the false impression that the consequences of the 2011 nuclear disaster are short lived and of limited effect. However, long after the Suga (and Abe) administrations are historical footnotes, the negative consequences of the Fukushima Daiichi meltdown will remain a present and constant threat – most immediately to the people and environment of Fukushima, but also to the rest of Japan and internationally.

As this report has detailed, two of the most hazardous of all radionuclides in the contaminated water are strontium and carbon-14, with half-lives of 30 and 5,730 years respectively. They will remain in the water to be discharged to the Pacific. In the case of the bone-seeking strontium-90, TEPCO and the Japanese government have known for years that the ALPS technology they chose was not the best available to deal with this. A decision was taken to award contracts to Japanese companies Toshiba and Hitachi and not to deploy technology by US company Purelite that had been shown to reduce concentrations of strontium and other radionuclides to non-detectable levels.

Subsequently, the goalposts were moved and the ALPS was required to reduce contamination to the less strict target of below regulatory limits, which permits higher levels of radioactive contamination to be discharged. The consequences of these decisions will be large deliberate releases of strontium-90, carbon-14 and other hazardous radionuclides into the Pacific Ocean over the coming decades. The science of this and its consequences has not been explained or even barely acknowledged by TEPCO or the Japanese government.

In the case of carbon-14 it is even worse. Only in August 2020, nearly ten years after the start of the disaster, did TEPCO admit that there was a carbon-14 problem with the contaminated water. And it is a serious problem. ALPS was never designed to remove carbon-14 and if the contaminated water is discharged to the Pacific, all of it will released to the environment. Carbon-14 is integrated in the carbon cycle; put simply, it is incorporated into all living matter to varying factors of concentration. With a half-life of 5,730 years, it is a major contributor to global human collective dose over the long term. The discharge means it will be delivered to local, regional and global populations for many generations. None of this has been explained by TEPCO or the Japanese government.

As we concluded two years ago, the ongoing contaminated water crisis at the Fukushima Daiichi is a consequence of decisions taken more than fifty years ago, a failure to act on evidence of major seismic and tsunami risks to the plant, and of course the events of March 2011 and subsequent decisions. No government or industry confronted by the scale and range of challenges resulting from the 2011 events would have been able to manage the disaster.

However, time after time, TEPCO and Japanese government bodies appear to have conspired to make the crisis worse. The disclosures by TEPCO that their processing technology has not performed as effectively as they had suggested to the people of Japan, is only the latest in a long history of misreporting and cover ups.[107]

As the Japanese government has moved towards its final decision on discharge, the deliberate misinformation and distortion of reality has continued. It continues to state that the Fukushima Daiichi ALPS tank water is not contaminated, including in evidence to United Nations human rights experts. This is clearly false. A proportion of radioactive tritium becomes organically bound and has the potential to cause genetic damage. Again, this has not been explained by the Japanese government and TEPCO. They have not listened to and supported Fukushima and Japanese citizens who will be most affected by the release of the contaminated water; it has been UN Special Rapporteurs who have sought to defend their human rights.

METI's own subcommittee explained that there are options for securing additional storage both on and off the site. These were ruled out as they would be complex to negotiate and take time. However, the entire aftermath of the Fukushima nuclear meltdown is complex and it will take time measured not in years or decades but in centuries to address. The hundreds of tons of molten fuel and debris, which is contaminating the water, contains radionuclides such as plutonium-239 with a half-life of 24,110 years. There is no prospect of this debris being removed over the coming years, and no solution for its safe storage.

Long-term storage is the only viable option. However, this is not acceptable to the Japanese government as the Fukushima contaminated water crisis highlights and exposes the complexity and consequences of operating nuclear power. In the minds of Tokyo policymakers, dumping the water into the Pacific creates the impression that substantial progress is being made in the early decommissioning of the Fukushima Daiichi reactors.

There has been sustained opposition to the discharge from citizens in Fukushima, as well as commercial bodies such as Japan's national federation of fisheries cooperatives, JF Zengyoren,[108] most municipal assemblies in Fukushima Prefecture, and from wider Japanese society. Opposition from Japan's nearest geographical neighbours, especially the Republic of Korea, shows that this is not only a domestic issue but impacts people and communities outside Japan and relates to international maritime law and the protection of the world's oceans. While the Japanese government is determined to discharge the contaminated water, opposition will continue. In the interests of protecting human rights, and the health and environment of the people of Fukushima, Japan and the wider international community, the only acceptable option remains long-term storage and processing of the contaminated water.

Appendix

List of 62 radionuclides targeted for 'removal' by ALPS to below regulatory limits – not including Tritium and Carbon 14

(Source: Table compiled by author with list of isotopes from TEPCO, Overview of the Multi-nuclide Removal Equipment (ALPS) at Fukushima Daiichi Nuclear Power Station 29, March, 2013, Tokyo Electric Power Company, see https://www.tepco.co.jp/en/nu/fukushima-np/handouts/2013/images/handouts_130329_01-e.pdf)

Number	Isotope	Half life	Number	Isotope	Half life
1	Rubidium 86 (Rb-86)	19 days	32	Barium 140 (Ba-140)	13 days
2	Strontium 89 (Sr-89)	51 days	33	Cerium 141 (Ce-141)	33 days
3	Strontium 90	29 years	34	Cerium 144 (Ce-144)	284 days
4	Yitrium 90 (Y-90)	64 hours	35	Praseodymium 144 (Pr-144)	17 minutes
5	Yitrium 91 (Y-91)	58 days	36	Praseodymium 144m (Pr-144m)	7.2 minutes
6	Niobium 95 (Nb-95)	35 days	37	Promethium 146 (Pm-146)	5.5 year
7	Technetium 99 (TC-99)	211,000 years	38	Promethium 147 (Pm-147)	2.6 years
8	Ruthenium 103 (Ru-103)	39 days	39	Promethium 148 (Pm-148)	5 days
9	Ruthenium 106 (Ru-106)	374 days	40	Promethium 148m (Pm-148m)	43 days
10	Rhodium 103m (Rh-103m)	56 minutes	41	Samarium 151 (Sm-151)	89 years
11	Rhodium 106 (Rh-103)	30 seconds	42	Europium 152 (Eu-152)	13 years
12	Silver 110m (Ag-110m)	250 days	43	Europium 154 (Eu-154)	9 years
13	Cadmium 113m (Cd- 113m)	14 years	44	Europium 155 (Eu-155)	5 years
14	Cadmium 115m (Cd- 115m)	45 days	45	Gadolinium 153 (Gd-153)	240 days
15	Tin 119m (Sn 119m)	293 days	46	Terbium 160 (Tb-160)	72 days
16	Tin 123 (Sn-123)	130 days	47	Plutonium 238 (Pu-238)	88 years
17	Tin 126 (Sn-126)	100,000 years	48	Plutonium 239 (Pu-239)	24,110 years
18	Antimony 124 (Sb-124)	60 days	49	Plutonium 240 (Pu-240)	6552 years
19	Antimony 125(Sb-125)	2.8 years	50	Plutonium 241 (Pu-241)	14 years
20	Tellurium 123m (Te-123m)	120 days	51	Americium 241 (Am-241)	430 years
21	Tellurium 125m (Te-125m)	58 days	52	Americium 242m (Am-242m)	141 years
22	Tellurium 127 (Te-127)	9 hours	53	Americium 243 (Am-243)	7,470 years
23	Tellurium 127m (Te-127m)	110 days	54	Curium 242 (Cm-242)	160 days
24	Tellurium 129 (Te-129)	69 minutes	55	Curium 243 (Cm-243)	29 years
25	Tellurium 129m (Te-129m)	34 days	56	Curium 244 (Cm-244)	18 years
26	Iodine 129 (I-129)	15.7 million years	57	Manganese 54 (Mn-54)	312 days
27	Caesium 134 (Cs-134)	2 years	58	Iron 59 (Fe-59)	45 days
28	Caesium 135 (Cs-135)	2.3 million years	59	Cobalt 58 (Co-58)	71 days
29	Caesium 136 (Cs-136)	13 days	60	Cobalt 60 (Co-60)	5 years
30	Caesium 137 (Cs-137)	30 years	61	Nickel 63 (Ni-63)	100 years
31	Barium137m (Ba-137m)	3 minutes	62	Zirconium 65 (Zn-65)	244 days

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 * Please be aware that these values are estimates calculated under various assumptions. Since, almost of all tritium in reactor buildings at Fukushima Daiichi NPS was generated in Units 1-3 before the accident, it is assumed that the total amount of tritium which existed before the accident can be included in the contaminated water, while using trial calculations as much as possible, and that the duration of disposal may vary depending on the amount of tritium remaining in the fuel debris and other materials in the buildings.
 * Contaminated water which will be additionally generated and daily radioactivity attenuation should be considered.
 * It should be noted that even after disposal of the ALPS treated water stored in the tanks is completed, treated water continues to be generated until the end of decommissioning.
95. Op.cit. METI, 10 February 2020.
96. UN OHCR, “Fukushima: Japan must not ignore human rights obligations on nuclear waste disposal – UN experts”, 9 June 2020, see https://www.ohchr.org/EN/NewsEvents/Pages/DisplayNews.aspx?NewsID=25940&LangID=E; and Kyodo News, “U.N. experts urge Japan not to rush discharge of radioactive water”, 9 June 2020, see https://english.kyodonews.net/news/2020/06/6f6afd14d6a4-un-experts-urge-japan-not-to-rush-discharge-of-radioactive-water.html
97. The four Special Rapporteurs were: Mr. Baskut Tuncak, Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes; Mr. Michael Fakhri, Special Rapporteur on the right to food; Mr. Clément Nyaletsossi Voule, Special Rapporteur on the rights to freedom of peaceful assembly and of association; and Mr. José Francisco Calí Tzay, Special Rapporteur on the rights of indigenous peoples.
98. OHCHR, “Joint Communication from Special Procedures”, 20 April 2020, see https://www.mofa.go.jp/files/100064085.pdf
99. Ibid.
100. MOFA, “Response to the Joint Communication from Special Procedures from the Government of Japan”, 12 June 2020, see https://www.mofa.go.jp/files/100064087.pdf
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102. Citizens' Alliance Stop Polluting the Ocean!, “Communication to to Mr.Baskut Tuncak, Special Rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes Mr. Michael Fakhri Special Rapporteur on the right to food Mr. Clément Nyaletsossi Voule, Special Rapporteur on the rights to freedom of peaceful assembly and of association Mr. Francisco Calí Tzay, Special Rapporteur on the rights of indigenous peoples, 10 July 2020.
103. Ishikawa Town, “Opinion against the release of tritium-contaminated water stored on the premises of the TEPCO Daiichi Nuclear Power Plant to protect the lives of fisheries and fishermen in Fukushima Prefecture”, 11 March 2020, (in Japanese), see https://www.greenpeace.org/japan/sustainable/story/2020/07/14/17127/
104. Ibid.
105. Baskut Tuncak served as UN special rapporteur on the implications for human rights of the environmentally sound management and disposal of hazardous substances and wastes from 2014 to 2020.
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