Problems of Discharging ALPS Treated Water from the Fukushima Daiichi Nuclear Power Station into the Sea

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Abstract

In April 2021, as a measure to deal with the contaminated water was that was generated by the Fukushima Daiichi Nuclear Power Plant after the Great East Japan Earthquake of March 11, 2011, the Japanese government decided to discharge it into the sea after it was purified by the Advanced Liquid Processing System (ALPS) until the concentration of radioactive materials within the "ALPS treated water," other than tritium, were below the regulatory limits, and after it was further diluted with seawater. However, local governments and individuals involved in the fishery trade in Fukushima have expressed concerns about reputational damage and are calling for a withdrawal of the offshore release policy. Concrete development of effective measures—such as improving credibility through thorough safety measures and transparent information disclosure, implementing measures to secure and expand distribution channels for marine products, etc., and compensation for any reputational damage that may occur—is essential to prevent impediments to the reconstruction process.

Introduction

The issue of dealing with contaminated water that contains high concentrations of radioactive materials has remained unresolved after the accident at the Fukushima Daiichi Nuclear Power Plant (hereafter referred to as "Fukushima Daiichi NPP") occurred during the Tohoku earthquake that hit Japan on March 11, 2011.[1] Fukushima Daiichi NPP is

* All information sourced from the Internet in this paper was as of September 24, 2021.

[1] On March 24, 2011, an accident occurred on the first basement floor of the turbine building of Unit 3, when three employees of TEPCO's partner company were exposed to contaminated water and radiation. This incident led to a recognition of the need to safely manage the highly

owned and managed by the Tokyo Electric Power Company (hereafter referred to as "TEPCO"). The government and TEPCO[2] have been studying ways to dispose of treated water[3] that contains reduced concentrations of radioactive materials while simultaneously

contaminated water found in the turbine buildings of Units 1 to 3. Subsequently, on March 27, a team was established within the "Fukushima Daiichi NPP Accident Response Integrated Liaison Headquarters" by the government and TEPCO to study the treatment of highly contaminated water and other issues. Although TEPCO was aware of the risk of highly contaminated water injected into the reactor leaking out of the reactor containment vessel and accumulating in the reactor building and eventually leaking out of the reactor building before this exposure accident occurred, TEPCO was busy dealing with higher priority issues such as reactor cooling to take measures to prevent water leakage and radiation exposure in the reactor. 『東京電力福島原子力発電所における事故調査・検証委員会『中間報告（本文編）』2011.12.26, pp.295-296, 330-331 (Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company, *Interim Report (Main Text)*, 2011.12.26, pp.295-96, 330-331). Cabinet Secretariat Website

2 On July 31, 2012, the government, through the Nuclear Damage Compensation Facilitation Corporation (currently known as the Nuclear Damage Compensation and Decommissioning Facilitation Corporation), underwrote shares issued by TEPCO (with a total paid-in amount of 1 trillion yen) and "effectively nationalized" the company by assuming majority voting rights in the entity. The Nuclear Damage Compensation and Decommissioning Facilitation Organization dispatch executives from the Ministry of Economy, Trade and Industry to TEPCO. In April 2016, TEPCO transitioned into a holding company and changed its trade name from "The Tokyo Electric Power Company Incorporated" to "Tokyo Electric Power Holdings Incorporated." It also transferred its fuel and thermal power generation business to "Tokyo Electric Power Fuel & Power Incorporated," its power transmission and distribution business to "Tokyo Electric Power Grid Incorporated," and its retail electricity business to "Tokyo Electric Power Company Energy Partner Incorporated." This paper uses the name "TEPCO" to refer to the entity even after the name change.

3 This paper uses "treated water" as a generic term that encompasses water that has been treated by facilities such as the cesium adsorption apparatus and the multi-nuclide removal equipment (ALPS). Further, in accordance with TEPCO's definition, the term "treated water" is used to refer to the following: water in which the concentrations of cesium and strontium were lowered from contaminated water (accumulated water) in the buildings—using the cesium adsorption apparatus—is called "strontium-removed water"; water treated by the cesium adsorption apparatus to meet the Nuclear Regulation Commission's regulatory standards for radioactive materials—other than tritium—before being treated using ALPS is called "ALPS treated water"; water treated by ALPS and does not meet the regulatory standards for radioactive materials—other than tritium—is called "water to be re-purified." When "water to be re-purified" and "ALPS treated water" are referred to collectively, the term "ALPS treated water, etc." is used.

The regulatory standard requires that the sum of the ratios to the concentration limits specified for every nuclide (sum of the ratios to regulatory concentration limits) must be less than 1 ("Notification of dose limits based on rules concerning the business of refining nuclear raw materials and nuclear fuel materials" [Nuclear Regulation Authority, Notification No. 8 of 2015, hereafter referred to as the "Dose Notification" in the footnotes], Appendix Table 1; "Notification to establish matters required for the safety of reactor facilities and the protection of specified nuclear fuel materials at TEPCO's Fukushima Daiichi NPP Facility" [Nuclear Regulation Authority, Notification No. 3 of 2013, hereafter referred to as the "Fukushima Daiichi NPP Facility Notification"], Article 8 Paragraph 1). The government used to refer to water that has been treated using ALPS to remove radioactive materials other than tritium (including water that still contains radioactive materials—other than tritium—which are above the regulatory limits) as "ALPS treated water." However, to prevent harmful rumors that may arise due to misunderstandings, since April 13, 2021, the term "ALPS treated water" is used only to refer to "water that meets the regulatory standards for environmental discharge of nuclides other than tritium." 「東京電力福島第一原子力発電所における ALPS 処理水の定義を変更しました」2021.4.13 ("Definition of ALPS treated Water Changed at TEPCO's Fukushima Daiichi NPP," 2021.4.13).

avoiding the leakage of contaminated water into the environment and reducing the amount of contaminated water generated. However, no decision has been reached due to a lack of understanding of local fisherfolk, residents, and the public. On the other hand, there have been increasing calls to release the ALPS treated water into the sea as land available for installing additional tanks to store the treated water is running out. Consequently, on April 13, 2021, the government decided on a policy to discharge the water into the sea (hereafter referred to as the "Basic Policy for ALPS Treated Water").[4]

This report summarizes the process that led to the decision made by the government on the Basic Policy for ALPS treated Water after the Fukushima Daiichi NPP (Chapters I and III) accident,[5] provides information on tritium—a radioactive material difficult to remove from treated water (Chapter II)—and describes the measures taken to deal with reputational damage (Chapter IV)—the biggest challenge to the implementation of discharge into the sea.

I　Background and Current Status of Contaminated Water

1　*Initial Response*

(1) Generation of Contaminated Water and its Discharge into the Sea

The tsunami triggered by the Great East Japan Earthquake on March 11, 2011, flooded reactor buildings 1-4 of the Fukushima Daiichi NPP, leading to a power outage in Units 1-3 that resulted in a loss of reactor core cooling. This led to a core meltdown, which melted the nuclear fuel elements inside the reactor. To reduce the temperature rising inside the reactor, TEPCO injected fresh water and seawater into the structure from the outside. However, the water became highly contaminated with radioactive materials after it came into contact with molten fuel and leaked from the reactor pressure and containment vessels into the reactor building that housed them and the adjacent turbine building.[6] There was a need to store the highly contaminated water within the central radioactive waste treatment facility—which was separate from Units 1-4—to prevent its leakage into the environment.

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4 廃炉・汚染水・処理水対策関係閣僚等会議「東京電力ホールディングス株式会社福島第一原子力発電所における多核種除去設備等処理水の処分に関する基本方針」2021.4.13 (The Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning issues, "Basic Policy on Handling of ALPS treated Water at the Tokyo Electric Power Company Holdings' Fukushima Daiichi Nuclear Power Station," 2021.4.13).

5 For an overview of the initial response to contaminated water and the progress in countermeasures, see 青山寿敏「福島第一原発の汚染水問題」『調査と情報—ISSUE BRIEF—』839 号, 2015.1.8, p.5 AOYAMA Hisatoshi, "The Question of Contaminated Water at the Fukushima Daiichi Nuclear Power Station," *Chosa to Joho: Issue Brief*, 839, 2015.1.8, p.5).

6 東京電力福島原子力発電所における事故調査・検証委員会　前掲注(1), p.330 (Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company), *op.cit* (1), p.330.

Therefore, between April 4 to 10, TEPCO was forced to release the seawater (with a low concentration of contamination) that had accumulated inside the facility during the tsunami.[7] Nevertheless, the advance explanation provided by TEPCO to the local community and neighboring countries was insufficient, which led to criticism and concern from home and overseas.[8]

Additionally, highly contaminated water was reported to have leaked into the sea from reactor 2 intake between April 1-6 and from reactor 3 intake on May 11.[9]

(2) Introduction of Circulating Water Injection Cooling and Installation of ALPS

After the Fukushima Daiichi NPP accident, it was essential to cool the reactor by injecting water continuously from the outside. Therefore, the amount of contaminated water that had accumulated in the basements of the buildings (accumulated water)—such as the reactor and turbine buildings in reactors 1-4 and the centralized waste disposal buildings—continued to rise. Consequently, on June 27, TEPCO responded by launching circulating water injection cooling on a massive scale. Circulating water injection cooling is a system that uses cesium adsorption apparatus, desalination system, etc., to remove cesium and salt from the accumulated water and this water is injected into the reactor as a coolant. (Although concentrated salt water that contained a high level of radioactive materials was also generated, it was stored in tanks.[10]). The system helped reduce the

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7 TEPCO also discharged water (low-concentration contaminated water) from the sub-drain wells of Units 5 and 6 into the sea, which was approximately 1,323 m^3. The amount released from the centralized waste treatment building was estimated at 9,070 m^3, and the estimated total amount of radioactivity released was 150 billion Bq (becquerels). 東京電力『福島原子力事故調査報告書』2012.6.20, pp.285-286 (TEPCO, *Fukushima Nuclear Accident Investigation Report*, 2012.6.20, pp.285-286).

8 The National Federation of Fisheries Co-operative Associations, the Fukushima Prefecture Federation of Fishermen's Cooperative Associations, and other fisherfolk's cooperative associations submitted a letter of protest to TEPCO regarding the discharge into the sea. Countries who disagreed with the decision to implement offshore release without prior notification and consultation with them—regardless of how low the concentrations were—also insisted that an understanding by Japan's neighboring countries should have been sought before the release of radioactive materials into the sea. 東京電力福島原子力発電所における事故調査・検証委員会　前掲注(1), pp.336, 359 (Investigation Committee on the Accident at Fukushima Nuclear Power Stations of Tokyo Electric Power Company, *op.cit.*.. (1), pp.336, 359).

9 The amount of outflow and radioactivity from Unit 2 was 520 m^3 and 4,700 trillion Bq, respectively, which comprised 2,800 trillion Bq of iodine-131, 940 trillion Bq of cesium-134, and 940 trillion Bq of cesium-137. The amount of outflow and radioactivity from Unit 3 was estimated at 250 m^3 and 20 trillion Bq, respectively, which included 9.8 trillion Bq of cesium-137, 9.3 trillion Bq of cesium-134, and 0.85 trillion Bq of iodine-131 ("Appendix VI-2" and "Appendix VI-3"). 原子力災害対策本部『原子力安全に関する IAEA 閣僚会議に対する日本国政府の報告書―東京電力福島原子力発電所の事故について―』2011.6 (Nuclear Emergency Response Headquarters, *Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety—The Accident at TEPCO's Fukushima Nuclear Power Stations*, 2011.6).

10 In addition to fresh water and concentrated salt water, other waste products such as adsorption towers and sludge were generated. 東京電力「放射性滞留水処理システムの概要について」

amount of water accumulated and ensured that a stable water level was maintained.[11] Unfortunately, groundwater continued to flow into the buildings (approximately 200–500 m^3 a day[12]), and the total volume of contaminated and treated water—which included accumulated water, concentrated salt water, etc.—was still increasing.[13]

To further reduce the concentration of radioactive materials found in the contaminated water, from March 2013, TEPCO began to operate three Advanced Liquid Processing System (ALPS)[14] units. Every unit could treat 250 m^3/day of contaminated water and remove most radioactive materials from concentrated salt water (ALPS treated water, etc. was stored in tanks).[15] However, the units were beset by a series of problems—such as malfunctioning filters—that prevented their stable operation, and the treatment process could not keep up with an increasing amount of contaminated water.[16]

2 *Progress of Measures*

(1) Formulation of a Basic Policy for the Contaminated Water Issue

In 2013, a report of leakage of contaminated water from an underground water

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2011.6.9, p.1 (TEPCO, "Outline of Radioactive Accumulated Water Treatment System," 2011.6.9, p.1). See infra note (149).

11 東京電力「福島第一原子力発電所 この一年の振り返り」2012.3, p.20 (TEPCO, "Fukushima Daiichi Nuclear Power Station: A Review of the Past Year," 2012.3, p.20).

12 TEPCO, *op.cit...* (7), p.290.

13 The total volume of contaminated and treated water had increased from 120,000 m^3 (before the commencement of circulating water injection cooling) to 200,000 m^3 (as of January 3, 2012). 山岸功ほか「福島第一原子力発電所高汚染水の処理処分の課題—処分を見据えた対応策の提言—」『アトモス—日本原子力学会誌—』54, 2012.3, p.167 (YAMAGISHI Isao et. al., "Issues of Treatment and Disposal of Highly Contaminated Water at Fukushima Daiichi Nuclear Power Plant—Proposal of Measures for Disposal with a View to Disposal," *ATOMO Σ–Journal of the Atomic Energy Society of Japan*, 54, 2012.3, p.167).

14 A device that can remove 62 types of radionuclides found in the contaminated water. However, it was not technologically possible to remove tritium. Although carbon-14 was also not designed to be removed, its concentration in the storage tanks (80 tanks were analyzed by the end of June 2020) for ALPS treated water, etc. was below the concentration limit specified in the Dose Notification (the regulatory concentration limit). 「多核種除去設備等処理水の貯蔵タンクにおける放射性炭素（C-14）の告示濃度比分布」 ("Distribution of the Ratios to Regulatory Concentration Limit of Radiocarbon (C-14) in Storage Tanks of Treated Water from the Advanced Liquid Processing System").

15 東京電力「主な対策の進捗状況」（汚染水処理対策委員会（第 15 回）参考 2-3）2015.3.17, p.3 (TEPCO, "Progress of Major Countermeasures," Committee on Countermeasures for Contaminated Water Treatment, Meeting No. 15, Reference 2-3, 2015.3.17, p.3).

16 青山　前掲注(5), p.5 (AOYAMA *op.cit...* (5), p.5).

reservoir into the site (in April)[17] and a seawall into the port (in July)[18] was confirmed. In August, approximately 300 m^3 of contaminated water leaked from a bolt-joint in a flanged tank used to store contaminated water, which highlighted the frequent occurrences of tank-related issues.[19]

In September 2013, the National Nuclear Emergency Response Headquarters[20] implemented a Basic Policy for the Contaminated Water Issue to solve the growing problem of tainted water.[21] The policy outlined fundamental measures to resolve the issue of contaminated water under three basic principles: (1) *remove* the contamination source; (2) *isolate* groundwater from the contamination source; (3) *prevent leakage*.[22] The government would also strengthen its response by taking the initiative to implement technically difficult measures. Specifically, these included the "installation of the land-side impermeable wall using a soil-freezing method" to prevent groundwater inflow and the "realization of a more advanced ALPS," which will be fully financed by the government.[23] In December 2013, based on the Basic Policy for the Contaminated Water Issue, the Nuclear Emergency Response Headquarters decided "Additional Measures Regarding Decommission and the Contaminated Water Issue" (hereafter referred to as "Additional Measures").[24]

Based on the Basic Policy for the Contaminated Water Issue and the Additional Measures, the following specific measures were implemented.

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[17] 東京電力「地下貯水槽からの汚染水漏えい及び対応状況について」（汚染水処理対策委員会（第 1 回）資料 2-3）2013.4.26 (TEPCO, "Leakage of Contaminated Water from an Underground Water Storage Tank and the Status of Response," Committee on Countermeasures for Contaminated Water Treatment, Meeting No. 1, Document 2-3, 2013.4.26).

[18] 福島県『原子力行政のあらまし―福島県原子力発電所の廃炉に関する取組―平成 25 年度』2014, p.10 (Fukushima, *Overview of Nuclear Power Administration—Efforts Concerning Decommissioning of the Fukushima Nuclear Power Plant FY 2013*, 2014, p.10). TEPCO estimated that the amount of radioactive materials that leaked into the port from May 2011 to July 2013 included 20-40 trillion Bq of tritium, 1-20 trillion Bq of cesium-137, and 0.7-10 trillion Bq of strontium-90. These figures did not include the accidental or intentional release of radioactive materials in April and May 2011. 東京電力「放射性物質（トリチウム・セシウム・ストロンチウム）の流出量の評価」2013.8.21 (TEPCO, "Assessment of the Amount of Leaked Radioactive Materials [Tritium, Cesium, and Strontium]," 2013.8.21).

[19] Fukushima Prefecture, *ibid.*, p.9.

[20] The Nuclear Emergency Response Headquarters was established in the Cabinet Office on March 11, 2011, under Article 16 of the "Act on Special Measures Concerning Nuclear Emergency Preparedness" (Act No. 156 of 1999) to promote emergency response measures for the Fukushima nuclear accident and is headed by the Prime Minister of Japan.

[21] 原子力災害対策本部「東京電力（株）福島第一原子力発電所における汚染水問題に関する基本方針」2013.9.3 (Nuclear Emergency Response Headquarters, "Basic Policy for the Contaminated Water Issue at TEPCO's Fukushima Daiichi NPP," 2013.9.3).

[22] *ibid.*, pp.3-6.

[23] *ibid.*, pp.1-2.

[24] 原子力災害対策本部「東京電力（株）福島第一原子力発電所における廃炉・汚染水問題に対する追加対策」2013.12.20 (Nuclear Emergency Response Headquarters, "Additional Measures for Decommissioning and Contaminated Water Issues in TEPCO's Fukushima Daiichi NPP," 2013.12.20).

(2) Measures to *Remove* the Contamination Source

To expedite the rate of purification of concentrated salt water, TEPCO installed three improved ALPS units that commenced operations in October 2014. After desalination treatment, the concentration of cesium is reduced; however, radioactive substances, such as strontium, are present in the concentrated salt water.[25] In the same month, one high-performance ALPS unit, which was subsidized by the Japanese government, commenced operations.[26] Consequently, the processing capacity was raised from 750 m^3/day to 2,000 m^3/day.

Additionally, the concentration of strontium in concentrated salt water was lowered through the use of mobile strontium removal equipment and improved cesium adsorption apparatuses. Consequently, treatment of concentrated salt water was completed in May 2015, and ALPS treated water, etc. and strontium removed water were stored in tanks.[27]

As there was a high risk of leakage of highly contaminated water that had accumulated in the underground tunnel (seawater piping trench) from the seaward side of the reactor building, it had to be removed. Hence, the removal process began in November 2014 by pumping the contaminated water from the tunnel before the trench was filled and sealed with special materials. By December 2015, the removal process and filling of the trenches were completed.[28]

(3) Measures to *Isolate* Groundwater from the Contamination Source

Since May 2014, one of the measures taken by TEPCO to control the inflow of groundwater into the buildings that originated from the mountain has been the use of groundwater bypass wells. The wells are located away from the nuclear reactor building on the mountain side, and groundwater has been pumped from the wells to reduce the amount that can reach the vicinity of the buildings.[29] After the groundwater is verified to have met

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25 The processing capacity of the improved ALPS is over 250 m^3/day. Based on the operational experience of the existing ALPS, improvements were made to lower the radioactive concentration. 東京電力「東京電力福島第一原子力発電所の現状と今後の対応について」2015.5.30, p.8 (TEPCO, "Current Status of TEPCO's Fukushima Daiichi NPP and Future Responses," 2015.5.30, p.8).

26 As the processing capacity is more than 500m^3/day, the amount of waste generated is reduced to approximately one-twentieth of that of the existing ALPS. (*ibid.*)

27 東京電力「今後のタンクの運用計画について」2016.3.3, pp.1-3 (TEPCO, "Future Tanks Operation Plan," 2016.3.3, pp.1-3). See *op.cit.*.(3) for strontium removed water, ALPS treated water, etc.

28 資源エネルギー庁『令和 2 年度エネルギーに関する年次報告（エネルギー白書 2021）』2021, p. 10 (Agency for Natural Resources and Energy, *Annual Report on Energy in FY 2020 (Energy White Paper 2021)*, 2021, p.10).

29 「③地下水バイパス（汚染源に水を近づけない対策）」2021.8.19. 経済産業省ウェブサイト（"③Groundwater Bypass Wells (Measure to *Isolate* Groundwater from the Contamination Source)," 2021.8.19.; 「地下水バイパス揚水井からの地下水汲み上げ」東京電力ホールディングスウェブサイト（"Pumping Groundwater from Groundwater Bypass Wells.")

the effluent standards[30], it is discharged into the sea.

Since September 2015, groundwater has been also pumped from sub-drain wells (or wells near the reactor buildings) and purified using dedicated equipment. After the water meets the operational requirements,[31] which are stricter than the effluent standards established for groundwater pumped from bypass wells, it is discharged into the port to control the inflow of groundwater into the buildings.[32] In February of the same year, after the discovery that TEPCO had not disclosed the outflow of highly contaminated water into the open sea whenever it rained, the Fukushima Prefectural Federation of Fisheries Co-operative Associations refused to approve the commencement of certain initiatives, which resulted in a temporary impasse.[33]

To prevent groundwater flowing from the mountain side to the seaward side and prevent groundwater from flowing into buildings, land-side impermeable walls were built to enclose Units 1-4. Covering a total length of approximately 1,500 m, the walls were constructed using a soil-freezing method. The freezing process commenced in March 2016 and was completed in September 2018, which involved a total frozen soil volume of 70,000 m^3.[34]

Finally, to prevent rainwater from flowing inside the buildings from the damaged

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[30] TEPCO has established operational targets below the regulatory concentration limits and the guidelines on drinking water quality issued by the World Health Organization (for tritium, the recommended level was 10,000 Bq/L). For example, the target level for cesium-134 and cesium-137 is 1 Bq/L; for total beta (strontium-90, etc.) and tritium, the target levels are 5 Bq/L and 1,500 Bq/L, respectively. 東京電力ホールディングス「地下水バイパスの運用目標（排水の基準）について」（多核種除去設備等処理水の取扱いに関する小委員会（第 2 回）資料 5）2016.12.16, p.3 (TEPCO, "Operational Targets (Effluent Standards) for the Groundwater Bypass Wells," Subcommittee on Handling of ALPS treated Water, Meeting No. 2, Document 5, 2016.12.16, p.3).

[31] The operational targets for of cesium-134, cesium-137, and tritium are similar to the amounts found in groundwater bypass wells, but the operational target for total beta (strontium-90, etc.) is stricter at 3 Bq/L. 廃炉・汚染水対策チーム, 東京電力福島第一廃炉推進カンパニー「サブドレン及び地下水ドレンの運用方針」2015.9 (Team for Countermeasures for Decommissioning and Contaminated Water Treatment, Fukushima Daiichi Decontamination and Decommissioning Engineering Company, "Sub-drain Well and Underground Water Drain Operation Policy," 2015.9).

[32] 「④サブドレン（汚染源に水を近づけない対策）」2021.8.19. 経済産業省ウェブサイト ("④Sub-drain Wells (Measures to *Isolate* the Contamination Source from Water," 2021.8.19); 「建屋近傍の井戸（サブドレン）からの地下水汲み上げ」東京電力ホールディングスウェブサイト ("Pumping of Groundwater from Wells Surrounding the Facilities (Sub-drain Wells).")

[33] アジア・パシフィック・イニシアティブ『福島原発事故 10 年検証委員会―民間事故調最終報告書―』ディスカヴァー・トゥエンティワン, 2021, p.267 (Asia Pacific Initiative, *The 10-year Investigation Commission on the Fukushima Nuclear Accident: Final Report*, 2021, p.267).

[34] 「⑤凍土方式の陸側遮水壁（汚染源に水を近づけない対策）」2020.9.24 ("⑤Land-side Impermeable Walls Made Using the Soil-freezing Method [to *Isolate* the Contamination Source from Water]," 2020.9.24). ;「凍土方式の陸側遮水壁の設置」("Installation of Land-side Impermeable Walls Using the Soil-freezing Method").

sections of buildings and underground and becoming contaminated water, the damaged sections of building roofs and ground surfaces are currently being repaired and paved, respectively.[35]

(4) Measures to *Prevent Leakage* of Contaminated Water

To minimize the risk of radioactive materials leaked into the sea, in October 2015, TEPCO completed installing a wall of steel pipe sheet-piles (sea-side impermeable wall) on the seaward side of Units 1-4. The depth and length of the wall were 30 m and 780 m, respectively. This led to a significant reduction in the amount of radioactive materials leaked into the sea, which was confirmed by studies that reported an improving trend in water quality around the ports.[36] To prevent groundwater from leaking into the sea, a liquid glass-based chemical solution was injected into the ground, making it more difficult for the water to flow through.[37]

Finally, to prevent leakages from tanks, TEPCO began to replace flanged tanks—which were made with steel plates bolted together—with the more reliable welded tanks. The entire replacement process was completed in March 2019.[38]

3 *Present Status of Contaminated Water Treatment*

Through the implementation of measures such as the construction of land-side impermeable walls (frozen soil walls), sub-drains, and groundwater bypass wells, the amount of contaminated water generated was reduced from approximately 540 m^3/day in May 2014—before the measures were introduced—to about 140 m^3/day in 2020, which

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[35] 東京電力ホールディングス「福島第一原子力発電所の汚染水処理対策の状況」(TEPCO, “Status of Contaminated Water Treatment Measures at the Fukushima Daiichi Nuclear Power Plant”); (汚染水処理対策委員会（第 23 回）資料 3）2021.6.25, pp.9-15 (Committee on Countermeasures for Contaminated Water Treatment, Meeting No. 23, Document 3, 2021.6.25, pp.9-15).

[36] 資源エネルギー庁 (Agency for Natural Resources and Energy), *op.cit.* (28), p.10.

[37] 東京電力「福島第一原子力発電所の汚染水の状況と対策について」（平成 27 年度第 6 回福島県原子力発電所の廃炉に関する安全確保県民会議　補足資料-2）2016.2.3, p.8 (TEPCO, “Status of Contaminated Water at the Fukushima Daiichi Nuclear Power Plant and Countermeasures,” Supplemental Material-2 to the Sixth Fukushima Prefectural Citizens’ Meeting on Safety Assurance Regarding Decommissioning of Nuclear Power Plants in FY 2015”, 2016.2.3, p.8).

[38] Additionally, double barriers were installed around the tanks to prevent the outflow of water leaking from the tanks into the external environment in the event of a leakage. 資源エネルギー庁 (Agency for Natural Resources and Energy), *op.cit.* (28), p.10.

met the medium to long-term target of “150 m^3/day by FY 2020.”[39,40] Moreover, the water levels in underground areas—such as the basements of the turbine buildings—were lowered after progress was made to transfer the accumulated water. Consequently, the floor surface remains exposed.[41]

As of April 1, 2021, approximately 16,000 m^3 of accumulated water remains in the reactor buildings and central radioactive waste treatment facility.[42] For this water body, the cesium adsorption apparatus reduces the concentration of cesium and strontium, which accounted for much of the radiation. Subsequently, the desalination system distills it into fresh water and strontium-removed water, which contained salt. The fresh water is used to cool the nuclear fuel, and the strontium-removed water undergoes ALPS treatment to remove nuclides—other than tritium—before it is stored in tanks.[43]

A total of 1,250,000 m^3 of treated water is stored in 1,047 tanks on the site, and the treated water contains approximately 780 trillion Bq (Becquerel) of tritium, with an average concentration of approximately 620,000 Bq/L (as of April 1, 2021).[44] By December 2020, TEPCO had secured approximately 1.37 million m^3 (or 1,061 tanks) of tank capacity.[45] If

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39 廃炉・汚染水対策関係閣僚等会議「東京電力ホールディングス（株）福島第一原子力発電所の廃止措置等に向けた中長期ロードマップ」2019.12.27, pp.13-15 (The Inter-Ministerial Council for Contaminated Water and Decommissioning Issues, “The Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station,” 2019.12.27, pp.13-15). According to the mid to long-term roadmap (*ibid.*, TEPCO, “The Mid-and-Long-Term Roadmap toward the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station,” 2015.6.12, p.9; *ibid.*.) developed in June 2015, the goal was to achieve a structure inflow amount of 100 m^3/day by FY 2016. However, with the formulation of a medium to long-term roadmap in September 2017, it was revised to the current goal, which aims to achieve a structure inflow amount of 100 m^3/day by 2025.

40 「廃炉・汚染水・処理水対策の概要」(“Outline of Decommissioning, Contaminated Water and Treated Water Management ”); (廃炉・汚染水・処理水対策チーム会合／事務局会議（第 91 回）資料 2）2021.6.24, pp.1, 4 (Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water, No. 91, Document 2, 2021.6.24, pp.1, 4, *ibid.*)

41 東京電力ホールディングス　前掲注(35), pp.23-24 (TEPCO Holdings, *op.cit.* (35), pp.23-24).

42 東京電力ホールディングス「福島第一原子力発電所における高濃度の放射性物質を含むたまり水の貯蔵及び処理の状況について（第 496 報）」2021.4.5, 添付資料 1 (TEPCO Holdings, “Situation of Storage and Treatment of Accumulated Water Containing Highly Concentrated Radioactive Materials at Fukushima Daiichi Nuclear Power Station [496th Release],” 2021.4.5, Attachment 1).

43 東京電力　前掲注(27), pp.1-3 (TEPCO, *op.cit.* (27), pp.1-3).

44 The breakdown is 1,236,000 m^3 of ALPS treated water, etc., and 20,000 m^3 of strontium removed water. Approximately 30% of “ALPS treated water, etc.” is “ALPS treated water,” and an estimated 70% is “water to be re-purified.” 東京電力ホールディングス「多核種除去設備等処理水の定義見直し及びタンクに保管されているトリチウム量について」（廃炉・汚染水・処理水対策チーム会合事務局会議（第 89 回）資料 1）2021.4.27, pp.1, 3 (TEPCO Holdings, “Review of the Definition of Treated Water of Multinuclear Species Removal System and the Amount of Tritium Stored in Tanks,” (Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water, No. 89, Document 1), 2021.4.27, pp.1, 3).

45 Of the 1,061 tanks, 1,020 units hold ALPS treated water, etc. Additionally, 27 storage tanks hold

contaminated water is generated at a rate of 150 m^3/day, it will reach approximately 1,340,000 m^3 by November 2022, but its storage can continue into the spring of 2023 when the process of discharging ALPS treated water commences.[46]

The effective dose[47] at the site boundary due to radiation from contaminated water and other waste materials generated by the Fukushima Daiichi NPP accident has met the national standard[48] of 1 mSv (millisievert)/year since March 2016 (0.92 mSv/year as of March 2021).[49]

II Overview of Tritium

1 *Properties*

Tritium (T or ^3H), also known as "hydrogen-3," is a radioactive isotope of hydrogen

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strontium-removed water, 12 hold desalination system-treated water, and 2 hold concentrated salt water. 「処理水ポータルサイト」東京電力ホールディングスウェブサイト (TEPCO Holdings, "Treated Water Portal Site").

46 東京電力ホールディングス「厳格な放射能濃度の測定・評価に必要な設備について」(廃炉・汚染水・処理水対策チーム会合／事務局会議（第 90 回）資料 3-8）2021.5.27, p.9 (TEPCO Holdings, "Facilities Necessary to Perform Thorough Measurements/Assessments of Radiation Concentrations," Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water, No. 90, Document 3-8, 2021.5.27, p.9). The existing tanks—with a capacity of 30,000 m^3—located in close proximity to the ALPS will be converted for use in the preparation for discharge of ALPS treated water into the sea. A new set of tanks with a similar capacity will be put into service in November 2022. For details on the release of ALPS treated water, see Chapter III (3. Decision on Discharge into the Sea).

47 A unit that expresses the severity and extent of radiation on the human body after exposure. See infra note (64).

48 "Items required for measures that should be taken at Tokyo Electric Power Co., Inc.'s Fukushima Daiichi Nuclear Power Station in line with the designation as the specified nuclear facility" (as determined by the Nuclear Regulation Authority on November 7, 2012, and hereafter referred to as "Items Required for Measures" in footnotes) stipulates that, "In particular, the effective dose at site borders (assessed value of effective dose, including additional release of radioactive materials from the entire facility) from debris and contaminated water generated since the disaster stored in the facility shall be less than 1 mSv/year by March 2013." Although this standard was achieved after an assessment in March 2013, the contaminated water stored in the underground reservoir was transferred to tanks located near the site borders after it leaked from the reservoir in April of the same year. Since December 2013, this standard had been exceeded. 原子力規制委員会「東京電力福島第一原子力発電所敷地境界における実効線量の制限の達成に向けた規制要求について」(特定原子力施設監視・評価検討会（第 33 回）参考 2）2014.2.26, p.1 (Nuclear Regulation Authority, "Regulatory Requirements for Achievement of Effective Dose Limit at the Site Border of TEPCO's Fukushima Daiichi NPP," Commission on Supervision and Evaluation of the Specified Nuclear Facilities, Meeting No. 33, Reference 2, 2014.2.26, p.1).

49 東京電力ホールディングス「福島第一原子力発電所構内の線量状況について」(廃炉・汚染水・処理水対策チーム会合／事務局会議（第 89 回）資料 4-6）2021.4.27, p.6 (TEPCO Holdings, "Dose Status at the Site of Fukushima Daiichi NPP," Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water, No. 89, Document 4-6, 2021.4.27, p.6).

difficult to remove from contaminated water.[50] Like hydrogen, it exists in the form of water and also occurs in organic matter. It emits low-energy beta rays and produces helium-3 (^{3}He), which is a result of radioactive decay (half-life of 12.3 years).[51] The radioactivity of tritium is halved after a period—which is equivalent to its half-life—has lapsed. Hence, after 120 years (or 10 half-lives later), its radioactivity is lowered to 1/1000.[52]

Radiation exposure from tritium is not caused by external exposure but by internal exposure through the ingestion of tritiated water by humans.[53] Tritium can enter the human body through three ways: (1) inhalation of airborne tritiated water through the nose and mouth; (2) absorption through the skin; (3) ingestion of tritiated water in food and drinks.[54] Ingested tritium follows the digestion process and is eventually excreted from the body as urine and feces.[55] Although the physical half-life of tritium is 12.3 years, its biological half-life[56] is approximately 10 days[57] because tritiated water ingested by humans is discharged from their bodies relatively quickly.

However, it is believed that approximately 5–6% of tritiated water ingested by the human body is converted into organically bound tritium (OBT) by replacing hydrogen atoms in organic compounds such as proteins, sugars, and fats stored in the body.[58] OBT remains in the body for a long time and has a biological half-life that lasts from 40 days to approximately one year.[59]

2 *Health Effects*

The effective dose coefficient[60] of tritium taken orally by adults is 1.8×10^{-8}mSv/Bq. For OBT, which has a significant impact, it is 4.2×10^{-8} mSv/Bq and is less than 1/300th of

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50 Hydrogen (^{1}H), deuterium (D or ^{2}H), and tritium (T or ^{3}H) are known isotopes of hydrogen. Hydrogen and deuterium are stable isotopes.

51 “Radioactive decay” is a phenomenon that occurs when an unstable nucleus transforms into a more stable nucleus. Owing to radioactive decay, some radiation—such as alpha or beta rays—is emitted by the nucleus. The time taken by the number of radionuclides to be halved during radioactive decay is called “half-life.” 日本原子力学会炉物理部会『原子炉の物理』2019, pp.54-55 (Reactor Physics Division, Atomic Energy Society of Japan, *Physics of Nuclear Reactors*, 2019, pp.54-55).

52 百島則幸「環境トリチウム―起源と被ばく―」『環境管理』47, 2018, p.3 (MOMOSHIMA Noriyuki, “Tritium in the Environment—Origin and Exposure,” *Environmental Evaluation*, 47, 2018, p.3).

53 日本放射線影響学会放射線災害対応委員会編「トリチウムによる健康影響」2019.11.11. (Japan Radiation Research Society, Radiation Hazard Response Committee, ed., “Health Effects of Tritium,” 2019.11.11).

54 *ibid.*

55 *ibid.*

56 The time taken by radioactivity to be halved after a radioactive material is ingested into the human body and excreted. (*ibid.*)

57 *ibid.*

58 *ibid.*

59 *ibid.*

60 The coefficient used to convert the amount of ingested radionuclide (Bq) into internal exposure dose (Sv).

the 1.3 × 10^{-5} mSv/Bq of cesium-137.[61] For the same Bq value, the effects of tritium on health are considerably smaller.[62]

Studies on the carcinogenic effect of tritium in mice had found that there is a threshold dose[63] for tritium-induced, life-shortening and carcinogenesis, which is between 3.6 mGy and 10 mGy[64] a day.[65] This means that the incidence of cancer is within the range of natural incidence, even after a lifetime of drinking approximately 140 million Bq of tritiated water per liter, which is equivalent to 3.6 mGy a day.[66] Studies that examined the effects of tritium on the brain and nervous system of rats exposed in utero through the drinking of tritiated water by pregnant rats had found a significant reduction in the brain weight of fetal rat pups and impaired learning and memory after they were exposed to 273 mGy and 92 mGy of tritium, respectively. A reduction in the cognitive function of mouse pups was also found after they were exposed to either 100 mGy or 300 mGy of tritium in the fatal stage.[67]

Experiments on animals and epidemiological studies have not demonstrated tritium to have any more biological effects compared to other forms of radiation or radionuclides.[68] However, most of the radiation impact research to date has analyzed the effects of exposure to relatively high doses, and there are few experimental systems today that can clearly

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[61] One of the typical radioactive materials (fission products) produced by the fission of enriched uranium in fuel in a nuclear reactor. In addition to beta rays, it emits gamma rays that can travel hundreds of meters through the air. It has a half-life of 30 years, which is longer than other fission products released during the Fukushima Daiichi NPP accident. For instance, the half-life of iodine-131 is 8 days; for Cesium-134, it is 2 years. 日本アイソトープ協会『セシウムの ABC』丸善出版, 2014, pp.8-11 (Japan Radioisotope Association, *ABCs of Cesium*, Maruzen Publishing, 2014, pp.8-11).

[62] 日本放射線影響学会放射線災害対応委員会編　前掲注(53) (Japan Radiation Research Society, Radiation Hazard Response Committee ed.), *op.cit.* (53)).

[63] The threshhold dose when symptoms (definite effects) showed little differences from that which appeared after exposure to radiation with a relevant dose had occurred. For example, it is 3 Sv in hair loss, 2.5-6 Sv in permanent sterility, and 0.5 Sv in cataracts. (*ibid.*)

[64] Gray (Gy) is the amount of energy absorbed by a unit mass of material that has been exposed to radiation (absorbed dose). Although the absorbed dose is the same, the magnitude of its effect on the human body varies depending on the type of radiation and energy. The equivalent dose (in Sv) is the weightage given to every type of radiation according to the magnitude of its effect, while the effective dose (in Sv) refers to the weightage given based on the sensitivity of different human organs and tissues to a sum of equivalent doses, which represents the effect on the entire human body. 環境省放射線健康管理担当参事官室・量子科学技術研究開発機構『放射線の基礎知識と健康影響　令和元年度版』（放射線による健康影響等に関する統一的な基礎資料上巻） 2020, p.36 (Radiation Health Management Division, Ministry of the Environment & National Institutes for Quantum Science and Technology, "Basic Information Regarding Health Effects of Radiation FY 2019 Edition," *Integrated Basic Material on Health Effects of Radiation, Volume 1*, 2020, p.36).

[65] 日本放射線影響学会放射線災害対応委員会編　前掲注(53) ((Japan Radiation Research Society, Radiation Hazard Response Committee ed., *op.cit.*(53)).

[66] *ibid.*

[67] *ibid.*

[68] 田内広「トリチウム水およびトリチウム化合物の生体影響について」（多核種除去設備等処理水の取扱いに関する小委員会（第 11 回）資料 3-1）2018.11.30, p.19 (TAUCHI Hiroshi, "Biological effects of tritiated water and tritiated compounds," Subcommittee on Handling of ALPS treated Water, Meeting No. 11, Document 3-1, 2018.11.30, p.19).

evaluate the health effects of low-dose and low-dose-rate exposure.[69] Moreover, notably, most studies on the biological effects of tritium were conducted using model animals, and the scientific basis of these studies cannot be applied directly to humans.[70]

However, some have argued that it is necessary to accumulate objective biological impact data and promote research on the stochastic effects of radiation to discuss whether exposure to low levels of tritium can affect human health.[71]

3 *Regulations*

(1) Regulations on Discharges from Nuclear Facilities

Nuclear power plants, including the Fukushima Daiichi NPP, can discharge gaseous radioactive waste that contains tritium through exhaust ventilation facilities that use filtration, dilution, and other methods to lower—as much as possible—the concentration of radioactive materials.[72] They can also discharge liquid radioactive waste through drainage facilities that use filtration, evaporation, dilution (by adding large amounts of water), and other methods to minimize the concentration of radioactive materials.[73] However, air and water expelled by these facilities may not exceed the concentration levels (hereafter referred to as "regulatory concentration limits"[74]) specified by the regulatory standards (Dose Notification[75]) of the Nuclear Regulation Authority.[76] Further, the

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69 日本放射線影響学会放射線災害対応委員会編 (Japan Radiation Research Society, Radiation Hazard Response Committee ed., *op.cit.*(53).

70 *ibid.*

71 馬田敏幸「トリチウムの生体影響評価」『Journal of UOEH—産業医科大学雑誌—』39, 2017.3, p.30 (UMATA Toshiyuki, "Biological Impact Assessment of Tritium," *Journal of University of Occupational and Environmental Health*, 39, 2017.3, p.30).

72 「実用発電用原子炉の設置、運転等に関する規則」(昭和 53 年通商産業省令第 77 号。以下、脚注において「実用炉規則」) 第 90 条第 3 及び第 4 号 ("The Rule for the Installation, Operation, etc. of Commercial Nuclear Power Reactors," Ordinance of the Ministry of International Trade and Industry, No. 77 of 1978, hereafter referred to in footnotes as "Commercial Reactor Rules," Article 90, Items 3 and 4); 「東京電力株式会社福島第一原子力発電所原子炉施設の保安及び特定核燃料物質の防護に関する規則」(平成 25 年原子力規制委員会規則第 2 号。以下、脚注において「福島第一原子炉施設規則」) 第 16 条第 3 及び第 4 号 ("The Rule for the Safety of Reactor Facilities and Protection of Specified Nuclear Fuel Materials at TEPCO's Fukushima Daiichi NPS," Nuclear Regulation Authority, Regulation No. 2 of 2013, hereafter referred to in footnotes as "Fukushima Reactor Rules," Article 16, Items 3 and 4).

73 実用炉規則第 90 条第 6 及び第 7 号; 福島第一原子炉施設規則第 16 条第 6 及び第 7 号 (Commercial Reactor Rules, Article 90, Items 6 and 7; Fukushima Reactor Rules, Article 16, Items 6 and 7).

74 線量告示第 8 条第 1 項(Dose Notification, Article 8, Paragraph 1)

75 「核原料物質又は核燃料物質の製錬の事業に関する規則等の規定に基づく線量限度等を定める告示」(平成 27 年原子力規制委員会告示第 8 号) ("Notification of dose limits based on rules concerning the business of refining nuclear raw materials and nuclear fuel materials," Nuclear Regulation Authority, Notification No. 8.)

76 For offshore release by reprocessing facilities, a concentration limit is not specified for every

regulatory concentration limit of tritium—the average concentration over a three-month period—in the air (in the form of water vapor) is 5 Bq/L and 60,000 Bq/L in water (Table 1).[77] The regulatory concentration limits in water are calculated as the average dose rate from drinking tritium-containing water daily for 70 years after birth, which would reach the effective dose limit (1 mSv/year[78]) based on the Dose Notification.[79]

If the air or water contains multiple types of radioactive materials, the ratio of every type to the regulatory concentration limit is derived. Under the law, the sum of these (sum of the ratios to regulatory concentration limits) must not exceed a value of 1.[80]

However, countries such as South Korea and the US have concentration limits for tritium lower than Japan. Although Canada, the UK, and France do not have concentration limits, they have regulations that limit the total amount of radioactive materials that can be discharged (Table 1).

In Japan, although there are no legal restrictions on the total amount of radioactive materials that can be released, the guidelines of the former Nuclear Safety Commission[81] had prescribed a target value—an effective dose of 0.05 mSv/year—for the dose received by the public around facilities as a result of the release of radioactive materials. To meet this dose target value, nuclear facilities have established their operational target value for

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radioactive material, including tritium. However, an effective dose limit of 0.25 mSv for 3 months is specified for the offshore release of radioactive waste. 「使用済燃料の再処理の事業に関する規則」（昭和 46 年総理府令第 10 号）第 16 条第 7 号; 線量告示第 8 条第 3 項 (“Spent Nuclear Fuel Reprocessing Implementation Rule,” Prime Minister’s Office, Ordinance No. 10, 1971, Article 16, Item 7; Dose Notification, Article 8, Paragraph 3.)

77 線量告示別表第 1; 福島第一原子炉施設告示第 8 条第 1 項 (Dose Notification, Appendix Table 1; Fukushima Daiichi NPP Facility Notification, Article 8, Paragraph 1.)

78 Article 2 of the Dose Notification stipulates that beyond the monitoring areas of nuclear power plants, the effective dose limit is 1 mSv/year. This provision does not apply to the Fukushima Daiichi NPP, where the “Items Required for Measures” are applicable instead. 前掲注(48)参照, *op.cit.*(48).

79 The dose coefficients and annual water intake that vary with age are published by the International Commission on Radiological Protection (ICRP), and they are used to calculate the regulatory concentration limits in water. 原子力規制庁「放射性廃棄物に対する規制について」（多核種除去設備等処理水の取扱いに関する小委員会（第 11 回）資料 3-2 (Nuclear Regulation Authority, “Regulations for Radioactive Waste,” Subcommittee on Handling of ALPS treated Water, Meeting No. 11, Document 3-2, 2018.11.30, p.7).

80 Dose Notification, Article 8, Paragraph 1; Fukushima Daiichi NPP Facility Notification, Article 8, Paragraph 1.

81 It was established by the Cabinet Office based on the “Atomic Energy Basic Law” (Act No. 186 of 1955) and the “Act for Establishment of the Japan Atomic Energy Commission and the Nuclear Safety Commission” (Act No. 188 of 1955, currently the “Act for Establishment of the Japan Atomic Energy Commission”). It was also responsible for monitoring and auditing the activities of regulatory agencies (such as the Ministry of Education, Culture, Sports, Science and Technology, and Ministry of Economy, Trade and Industry). However, it was abolished after the Nuclear Regulation Authority was established in September 2012. Some of the guidelines developed by the Nuclear Safety Commission are still practiced by the Nuclear Regulation Authority in its regulatory activities.

the annual discharge of radioactive materials.[82] In the case of tritium, an "operational standard value for discharge" is set only for liquid wastes, such as 220 trillion Bq/year by Takahama NPP, 170 trillion Bq/year by Ooi NPP, and 110 trillion Bq/year by Kawauchi NPP.[83] The dose target value is an effort target, and a failure to attain it should not be interpreted as a safety hazard that necessitates the implementation of measures, such as suspension of operations or output restriction.[84] For the Rokkasho Reprocessing Plant of Japan Nuclear Fuel Limited, the operational target value for discharge of tritium is 1,000 trillion Bq/year and 9,700 trillion Bq/year for gases and liquids, respectively.[85]

Table1 **Regulations on the Release of Tritium by Nuclear Facilities and Concentration Standards for Tritium in Drinking Water According to Country**

Country	Regulations on Nuclear Facility Discharges			Concentration Standards for Drinking Water
	Regulatory Method	Gaseous Waste	Liquid Waste	
Japan	Concentration regulation	5 Bq/L	60,000 Bq/L (nuclear power) None (reprocessing)	None
South Korea	Concentration regulation	3 Bq/L	40,000 Bq/L	None
US	Concentration regulation	3.7 Bq/L	37,000 Bq/L	740 Bq/L
Canada	Total volume regulation	120–850 quadrillion Bq/year	370–46,000 quadrillion Bq/year	7,000 Bq/L
UK	Total volume regulation	3–15 trillion Bq/year (nuclear power) 1,100 trillion Bq/year (reprocessing)	80–700 trillion Bq/year (nuclear power) 18 quadrillion Bq/year (reprocessing)	100 Bq/L
France	Total volume regulation	4 trillion Bq, 4.5 trillion Bq/year, etc. (nuclear power) 150 trillion Bq/year (reprocessing)	45 trillion Bq, 80 trillion Bq/year, etc. (nuclear power) 18.5 quadrillion Bq/year (reprocessing)	100 Bq/L

82 「発電用軽水型原子炉施設周辺の線量目標値に関する指針」（昭和 50 年 5 月 13 日原子力委員会決定、平成元年・13 年一部改訂）p.1 (“Regulatory Guide for the Annual Dose Target for the Public in the Vicinity of Light Water Nuclear Power Reactor Facilities” decided by the Japan Atomic Energy Commission on May 13, 1975, and partially revised in 1989 and 2001, p.1). The website of the Nuclear Safety Commission is archived under the National Diet Library’s Web Archiving Project (WARP).

83 福井県環境放射能測定技術会議「原子力発電所周辺の環境放射能調査―2020 年（令和 2 年）度第 3 四半期報告書―」p.82 (Fukui Prefecture Technical Conference on Environmental Radioactivity Measurement, “Environmental Radioactivity Survey around Nuclear Power Plants—2020 Third Quarter Report,” p.82); 九州電力「川内原子力発電所 1 号機運転状況（令和 2 年 7 月～9 月）」（令和 2 年度第 4 回原子力安全対策連絡協議会　資料 3-1）2021.1.28 (Kyushu Electric Power, “Operational Status of Sendai Nuclear Plant I: July to September 2020,” Fourth Conference on Nuclear Safety Measures FY 2020, Document 3-1, 2021.1.28).

84 「発電用軽水型原子炉施設周辺の線量目標値に関する指針」前掲注(82), p.1 (“Regulatory Guide for the Annual Dose Target for the Public in the Vicinity of Light Water Nuclear Power Reactor Facilities,” *op.cit.*(82), p.1).

85 日本原燃『再処理事業所再処理事業変更許可申請書　本文及び添付書類の一部補正について』（令和 2 年 4 月 28 日再計発第 31 号）pp.508, 510 (Japan Nuclear Fuel Ltd., Partial Amendment to the Main Text and Attached Documents for Application for Permission for Change of Reprocessing Business at a Reprocessing Plant, No. 31, April 28, 2020, pp.508, 510).

(Note) "Nuclear power" refers to regulations on nuclear power plants, and "reprocessing" refers to nuclear reprocessing facilities. Although no concentration limits have been established for tritium and other radioactive materials by nuclear reprocessing facilities in Japan, an effective dose limit of 0.25 mSv over a three-month period has been established for the release of radioactive waste into the sea. In Canada, the UK, and France, regulations are put in place on a facility basis. One quadrillion becquerel denotes 1×10^{15} becquerel.

(Sources) Prepared by the author based on 三菱総合研究所『平成 30 年度原子力の利用状況等に関する調査事業（多核種除去設備等処理水の処分技術等に関する調査研究）調査報告書』2019.3.29, pp.38, 41 (Mitsubishi Research Institute, *Investigation Report of the Survey Project Regarding the Utilization of Nuclear Energy in FY 2018: Research on the Disposal Technology of ALPS treated Water*, 2019.3.29, pp.38, 41); 柿内秀樹「トリチウムの環境動態及び測定技術」『アトモス―日本原子力学会誌―』60, 2018.9, p.32 (KAKIUCHI Hideki, "Tritium in the Environment and its Evaluation Methods," *ATOMOΣ—Journal of the Atomic Energy Society of Japan*, 60, 2018.9, p.32).); Canadian Nuclear Safety Commission, "Standards and Guidelines for Tritium in Drinking Water," *Part of the Tritium Studies Project*, INFO-0766, 2008.

(2) Concentration Standards on Drinking Water

Based on the recommendations given by the International Commission on Radiological Protection (ICRP), the World Health Organization (WHO) has provided guidance levels that should govern the concentration of radionuclides in drinking water, including a concentration that can result in an effective dose of 0.1 mSv. For tritium, the threshold value is 10,000 Bq/L.[86]

Based on the WHO guidelines, Japan has only set operational target values for discharge of radioactive cesium (sum of cesium-134 and cesium-137) found in tap water. Owing to the limited number of measuring instruments currently available and the vast amount of time required for measurements, Japan has not prescribed operational targets for the discharge of any other radioactive materials, including tritium.[87]

However, many countries in the Western hemisphere have established standards on tritium concentrations in drinking water (Table 1). In Canada, guidelines were developed based on the recommendations of ICRP and other radiation protection concepts.[88] Consequently, a concentration of 7,000 Bq/L of tritium was established as the maximum

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[86] Guidance levels "are conservative and should not be interpreted as limits to be followed as mandatory. Exceeding the guidance level should be considered an opportunity for additional investigation and does not necessarily indicate that the drinking water is unsafe." WHO 編，国立保健医療科学院訳『飲料水水質ガイドライン　第 4 版（日本語版）』（翻訳 ver.2.1・Web 版）2012, pp.210, 215-216 (The WHO [translated by the National Institute of Public Health of Japan], *Guidelines for Drinking Water Quality, Fourth Edition (Japanese Version)*, translated version 2.1, online edition, 2012, pp.210, 215-216)).

[87] "(Appendix) Review of Indicators Related to Radioactive Substances in Tap Water," 厚生労働省健康局水道課長『水道水中の放射性物質に係る管理目標値の設定等について』（平成 24 年 3 月 5 日健水発 0305 第 1 号）p.3 (Director, Water Supply Division, Health Service Bureau, Ministry of Health, Labor and Welfare, *Establishment of Operational Target Values Related to Radioactive Substances in Tap Water*, March 5, 2012, No. 0305-1, p.3).

[88] Canadian Nuclear Safety Commission, "Standards and Guidelines for Tritium in Drinking Water," *Part of the Tritium Studies Project*, INFO-0766, 2008, p.11.

level that can be found in drinking water,[89] and it was adopted as the legal standard by Alberta, Manitoba, Ontario, and Quebec.[90] In the US, the maximum concentration level is 740 Bq/L, which is based on a dose limit of 0.04 mSv/year and previous radiological concepts that differed from the current guidelines and recommendations made by ICRP and the WHO.[91] Although the UK and France have an even lower threshold at 100 Bq/L, this limit is only used as an indicator. When it is exceeded, the presence of artificial radionuclides—other than tritium—need to be investigated.[92]

4 *Status of Discharge*

Tritium originates from artificial and natural sources. Owing to the cosmic rays found in the upper atmosphere of the earth, approximately 70 quadrillion (7×10^{16}) Bq of tritium is generated in the atmosphere. Nevertheless, a natural state of equilibrium was achieved through its decay on earth.[93] However, atmospheric nuclear tests conducted from 1945 to 1963 had artificially generated about 180-240 quintillion Bq[94] of tritium, which significantly affected this state of natural equilibrium.[95] Although much of this tritium was eliminated through radioactive decay, about nine times as much as the naturally occurring tritium remains today, it is widely and sparsely distributed in oceans worldwide.[96]

Currently, man-made tritium is released by production facilities mainly involved in its production as a raw material for hydrogen bombs and nuclear facilities such as nuclear power plants and nuclear reprocessing facilities (Table 2).[97] Among nuclear facilities, those involved in reprocessing release more tritium than nuclear power plants. Among the nuclear power plants, heavy-water reactors developed by Canada—also known as CANDU reactors—and installed in South Korea and Romania produce more tritium than light-water reactors.[98] Among the light-water reactors, pressurized water reactors release more tritium

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[89] Health Canada, "Guidelines for Canadian Drinking Water Quality: Summary Table," 2020.9, p. 23.
[90] Canadian Nuclear Safety Commission, *op.cit.*(88), pp.6, 18.
[91] *ibid.*, pp.9-11.
[92] 三菱総合研究所『平成 30 年度原子力の利用状況等に関する調査事業（多核種除去設備等処理水の処分技術等に関する調査研究）調査報告書』2019.3.29, p.43 (Mitsubishi Research Institute, Investigation Report of the Survey Project Regarding the Utilization of Nuclear Energy in FY 2018: Research on the Disposal Technology of ALPS treated Water, 2019.3.29, p.43).
[93] *ibid.*, p.5.
[94] A quintillion (10^{18}) is 1000 times a quadrillion (10^{15}), or a million times a trillion (10^{12}).
[95] Mitsubishi Research Institute, *op.cit.*. (92), p.5.
[96] MOMOSHIMA, *op.cit.*. (52), p.4.
[97] *ibid.*, p.4.
[98] 百島則幸「環境中のトリチウム」『トリチウム研究会―トリチウムとその取り扱いを知るために―』（講演資料）2014.3.4, p.1 (MOMOSHIMA Noriyuki, "Tritium in the Environment," *Tritium Study Group—Information about Tritium and Its Handling*, Lecture Material, 2014.3.4, p.1). In the CANDU reactor, heavy water (D2O) is used to moderate neutrons. In the process, deuterium (D or 2H) takes in neutrons, and tritium is produced. 岡本孝司「原子力なんでもQ&A　106　韓国のトリチウム　環境放出はどうですか。」『エネルギーレビュー』41,

than boiling water reactors.[99] Tritium discharged into the sea by nuclear facilities has been diluted with large amounts of seawater. Additionally, when it is released into the environment as gaseous waste from chimneys, it falls either directly or by rain into the vicinity of the facility, but is diluted by rain.[100]

***Table 2.* Tritium Discharge from Nuclear Power Plants and Nuclear Reprocessing Facilities in Major Countries** (Unit: trillion Bq)

Japan (2018)

Facility Name	Gaseous	Liquid
Sendai	1	34
Genkai	0	28
Oi	5	22
Takahama	5	19
Ikata	1	5
Mihama	4	2
Tsuruga	1	0
Tomari	0	0
Onagawa	0	0
Fukushima Daini	0	0
Hamaoka	0	0
Shimane	0	0
Tokai Daini	0	0
Higashidori	0	ND
Kashiwazaki-Kariwa	0	ND
Shika	0	ND
Tokai	0	ND
Fukushima Daiichi	0	–
TOTAL	18	109
Tokai Reprocessing Plant	0	0
Rokkasho Reprocessing Plant	0	0

US (2018)

Facility Name	Gaseous	Liquid
Watts Bar 1	1	145
Seabrook	4	61
Byron 1	0	52
Byron 2	2	52
South Texas	3	46
Braidwood 1	8	45
Braidwood 2	8	45
Watts Bar 2	1	44
Comanche Peak 1	1	39
Comanche Peak 2	1	39
Diablo Canyon 1	1	39
Diablo Canyon 2	1	39
Wolf Creek	1	38
Surry 1	1	34
Surry 2	1	34
Palisades	1	33
Sequoyah 1	0	31
Sequoyah 2	0	31

South Korea (2019)

Facility Name	Gaseous	Liquid
Kori, Shin Kori	23	92
Hanul	13	64
Wolseong, Shin Wolsong	101	31
Hanbit	16	18
TOTAL	153	205

Canada (2018)

Facility Name	Gaseous	Liquid
Bruce B	386	560
Bruce A	608	196
Pickering 5-8	320	280
Pickering 1-4	300	140
Darlington	210	220
Point Lepreau	140	240
Gentilly-2	92	55
TOTAL	2056	1691

2021.6, pp.51-52 (OKAMOTO Koji, "Nuclear Q&A 106: What about Tritium Released to the Environment in South Korea?," *Energy Review*, 41, 2021.6, pp.51-52).

99 MOMOSHIMA, *op.cit.*. (52), p.4.

100 MOMOSHIMA, *op.cit.*. (98), p.1.

UK (2019)

Facility Name	Gaseous	Liquid
Heysham 2	2	369
Hartlepool	1	333
Torness	1	323
Heysham 1	1	286
Hinkley Point B	2	217
Sizewell B	0	28
Hunterston B	1	21
Dungeness B	0	11
Chapelcross	30	0
Sellafield Reprocessing Plant	56	423

France (2019)

Facility Name	Gaseous	Liquid
Cattenom	3	117
Paluel	2	86
Civaux	1	70
Golfech	1	63
Saint-Alban	1	62
Gravelines	2	61
Bugey	1	57
Penly	1	53
Belleville	1	52
Chinon	1	51
Dampierre	1	50
Chooz	1	49
Blayais	1	44
Cruas	1	43
Nogent-sur-Seine	1	42
La Hague Reprocessing Facility	66	13,200

(Note) The data for Japan, Canada, and South Korea included all commercial nuclear power plants (and nuclear reprocessing plants in the case of Japan). For other countries, only commercial nuclear power plants (and nuclear reprocessing facilities) with a high discharge of tritium (liquid) were included. In the tables, “0” refers to an actual discharge of less than 0.5 trillion Bq. For Japan, “ND” denotes “Not Detected,” and “–” denotes “No Record of Release.” For the US, curie (Ci) was converted to Bq (1 Ci = 370 billion Bq).

(Sources) Prepared by the author based on 「［実用発電用原子炉に係る］放射線業務従事者線量等報告書　平成 30 年度分」2019.5.15 (“Report on Radiation Worker Doses, etc., for Commercial Power Reactors for FY 2018,” 2019.5.15); 「［再処理施設に係る］放射線業務従事者線量等報告書　平成 30 年度分」2019.5.15 (“Report on Radiation Worker Doses, etc., for Reprocessing Facilities for FY 2018,” 2019.5.15); US NRC, *Radioactive Effluents from Nuclear Power Plants: Annual Report 2018*, 2020.11, pp.3-12, 3-18; Government of Canada, *Canadian National Report for the Convention on Nuclear Safety, Eighth Report*, 2019.8, pp.257-258; ASN, “INVENTAIRE DES EMISSIONS DE TRITIUM – SYNTHESE – période 2015-2019,” *Livre Blanc du Tritium*, 2021.1.29, pp. 282–283; Environment Agency et al., *Radioactivity in Food and the Environment, 2019*, 25th edition, 2020.12, pp.240-249; 『한국수력원자력주식회사『원자력발전소 주변 환경방사능 조사 및 평가 보고서（2019 년도）』pp.61-62, 408-409, 573-574, 714. (Korea Hydro & Nuclear Power Co., Ltd. (KHNP), *Around Nuclear Power Plants: Environmental Radioactivity Survey and Assessment Report (FY 2019)*, pp.61-62, 408-409, 573-574, 714.)

Between 1998 and 2002, the global annual average of tritium release into the atmosphere and water was estimated at 11.7 quadrillion Bq and 16 quadrillion Bq, respectively.[101]

[101] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), *Sources, Effects and Risks of Ionizing Radiation—UNSCEAR 2016: Report to the General Assembly, with Scientific Annexes*, 2017, p.250.

III Review by the Government

As mentioned above, the government has taken measures to address the issue of contaminated water by *removing* the source of the contamination, *isolating* ground water from the contamination source and *preventing leakage* of the contaminated water. Simultaneously, measures were also considered to deal with issues such as the constant increase in the volume of ALPS treated water, etc. generated.

1 *Tritiated Water Task Force*

The Additional Measures state, "A comprehensive evaluation of all options for the handling of tritiated water, the storage of which in large volumes still has risks associated even after the implementation of Additional Measures, will be conducted as soon as possible, and these measures will be examined."[102] Consequently, the Committee on Countermeasures for Contaminated Water Treatment[103] established the Tritiated Water Task Force to examine and consider various options to handle ALPS treated water, etc.
In December 2013, the Task Force launched its investigations, and a report (hereafter referred to as the "Task Force report") was compiled by the team in June 2016.[104] The report summarized the basic requirements (including technical and regulatory feasibility) and potentially restricting conditions—such as duration, costs, and scale (including area required for disposal, secondary waste, and radiation exposure by workers)—for geosphere injection, discharge into the sea, vapor release, hydrogen release, and underground burial to determine the long-term management of ALPS treated water, etc. at the Fukushima Daiichi NPP. Table 3 provides a summary of the main options.[105]

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[102] Nuclear Emergency Preparedness Headquarters, *op.cit.*(24), p.1.

[103] The Committee was established in April 2013 under the Council for the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Station (currently known as the "Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues") to examine the fundamental measures that can be taken to resolve the issue of treating contaminated water and deal with accidents related to the leakage of contaminated water. Its members comprise staff from the Nuclear Emergency Preparation Headquarters, Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, TEPCO, companies related to nuclear power, and experts from universities and research institutes.

[104] トリチウム水タスクフォース「トリチウム水タスクフォース報告書」2016.6 (The Tritiated Water Task Force, "The Tritiated Water Task Force Report," 2016.6).

[105] From 2014 to 2016, the Ministry of Economy, Trade and Industry (METI) conducted a study on the latest technologies being developed on tritium separation. However, none of them could be put to immediate practical use. Consequently, in their report, the task force did not make any reference to the time and cost required for tritium separation. (*ibid.*, p.13)

Table3 **Comparison of Methods to Manage ALPS treated Water, etc.**

	Geosphere Injection	**Discharge into the Sea**	**Vapor Release**	**Hydrogen Release**	**Underground Burial**
Technical feasibility	Treatment cannot be initiated if a suitable geosphere layer is not found. Suitable monitoring methods have not been established.	There are cases of discharging tritium-containing liquid waste into the sea at nuclear facilities.	The nuclear power plant on Three Mile Island is an example of the evaporation method that uses a boiler.	It may be necessary to conduct technical development for pretreatment and scale expansion to handle treated water.	There are records of concrete pit and isolated-type disposal sites.
Regulatory feasibility	Depending on the disposal concentration, the establishment of new regulations and standards may be necessary.	Regulations and standards exist.	Regulations and standards exist.	Regulations and standards exist.	Development of new regulatory standards may be necessary.
Duration	104 + 20n months 912 months (monitoring)	91 months	120 months	106 months	98 months 912 months (monitoring)
Cost	18 + 0.65n billion yen + monitoring	3.4 billion yen	34.9 billion yen	100 billion yen	243.1 billion yen
Scale	380m^2	400m^2	2,000m^2	2,000m^2	285,000m^2
Secondary waste	None in particular.	None in particular.	Depending on the composition of the treated water, incinerator ash may be produced.	Residue may be produced as secondary waste.	None in particular.
Radiation Exposure to Workers	Nothing to consider in particular.	Nothing to consider in particular.	As the height of the exhaust pipe will be sufficiently high, other considerations are not necessary.	As the height of the exhaust pipe will be sufficiently high, other considerations are not necessary.	Covers must be installed to control worker exposure during burial.
Others	Costs and duration of exploration will increase unless suitable land is found.	An increase in costs are expected if a quay wall or another divider is installed between the intake water and the discharge outlet.	Depending on the precipitation conditions, the duration may be extended because operations may be suspended.	Depending on the precipitation conditions, the duration may be extended because operations may be suspended.	A lot of concrete and bentonite (a type of clay rock) are required. Construction spoil will be generated.

(Note) "Duration," "Cost," and "Scale" indicate the figures that will be incurred to dispose 400,000 m^3 of ALPS treated water, etc. (total 800,000 m^3) with concentrations of 4.2 million Bq/L and 500,000 Bq/L, respectively, while "n" indicates the number of times a geologic formation survey is conducted.

(Source) Prepared by the author based on 多核種除去設備等処理水の取扱いに関する小委員会「多核種除去設備等処理水の取扱いに関する小委員会報告書」2020.2.10, pp.6-7 (Subcommittee on Handling of ALPS Treated Water, "Report of the Subcommittee on Handling of ALPS Treated Water," 2020.2.10, pp.6-7).

2 *ALPS Subcommittee*

In September 2016, based on the technical findings compiled by the Tritiated Water Task Force, the Committee on Countermeasures for Contaminated Water Treatment established a "Subcommittee on Handling of ALPS Treated Water" (hereafter referred to as the "ALPS Subcommittee") to conduct a comprehensive review of the management of ALPS treated water, etc. and its social aspects, such as reputational damage.

For the review, the ALPS Subcommittee held hearings on the causes and extent of reputational damage and the measures that had been taken by the national and prefectural governments and other stakeholders to address it. In August 2018, it also held explanatory and public hearings in Fukushima and Tokyo. At these hearings, views against the discharging of ALPS treated water into the sea were heard, which included concerns about the safety of ALPS treated water, etc. stored in tanks and rumors on its harmful effects.[106] The findings of these hearings were compiled into a report in February 2020 (Table 4).[107]

Among the five methods of disposal of ALPS treated water considered by the Tritiated Water Task Force, vapor release and discharge into the sea—which were identified as technically feasible—were presented as realistic options. Discharge into the sea, in particular, was assessed as being "more reliable to implement than vapor release, given its track record with conventional reactors, the ease of handling discharge equipment, and the monitoring methods used."[108] The report also urged the government to be attentive to the opinions of diverse stakeholders—including local residents—and determine a policy that includes the method of disposal and one that incorporates measures to counter the impact of rumors.[109]

Table4 **Summary of the ALPS Subcommittee Report**

[Basic Approach] • It is important to proceed with the reconstruction of Fukushima and decommissioning of the reactor, and when decommissioning is completed, the ALPS treated water, etc. must be completely disposed of as one of the decommissioning tasks. • The disposal of ALPS treated water, etc. must not be rushed during the decommissioning process to ensure that it does not cause further reputational damage and hinder the progress of reconstruction. It is important to dispose of the ALPS treated water by considering its reputational impact while maintaining necessary storage.
[Current Situation] • There is limited room to install more tanks at the Fukushima Daiichi NPP site beyond what is currently planned.

106 The following materials summarized the opinions expressed at the explanatory and public hearings and the responses given to them by the ALPS Subcommittee. 「頂きました御意見に対する回答」("Responses to the Opinions Received").

107 多核種除去設備等処理水の取扱いに関する小委員会「多核種除去設備等処理水の取扱いに関する小委員会報告書」2020.2.10 (Subcommittee on Handling of ALPS Treated Water, "Report of the Subcommittee on Handling of ALPS treated Water," 2020.2.10). *ibid.*

108 *ibid.*, p.40.

109 *ibid.*, pp.2-3.

- Given a vast amount of leakage that can occur in the event of damage, no advantage can be yielded by the installation of large-capacity tanks—either aboveground or underground—at the Fukushima Daiichi NPP site.
- Tank storage can only be continued on-site, as the transportation of radioactive waste offsite would create more risks and require significant coordination and time to obtain the understanding from local municipalities and government approval.
- If the sum of ratios to regulatory concentration limits for radioactive materials other than tritium is 1 or more, secondary treatment should be performed before dilution to ensure that the sum of ratios to regulatory concentration limits is less than 1 before releasing the radioactive material into the environment..
- As the techniques for tritium separation are not at a stage for practical use at the Fukushima Daiichi NPP, it is assumed that tritium separation cannot be practiced.
- Tritium is a radioactive material produced in nature and is found naturally in water in the form of water vapor, rainwater, and seawater, as well as in the human body, and it has a lower impact on health than other radioactive materials.
- Although nuclear facilities in Japan and overseas have released radioactive materials—including tritium—into the sea or as steam, no common tritium-related effects have been found in the vicinity of these facilities.

[Investigation of Methods of Disposal]

- It is important to consider a balance between the timing of disposal, duration and amount for disposal, economic situation of local businesses, and sociopsychological circumstances by considering the duration required to implement these measures to reduce their impact on rumors.
- The government should decide on the commencement and duration of disposal after hearing the opinions of relevant parties and considering the timeline and reputational impact.
- Based on the social impact that may arise from each method of disposal, measures need to be taken to prepare for possible reputational damage that may occur after disposal.
- The three options for tritium disposal that have no precedents—geosphere injection, hydrogen release, and underground burial—present several challenges as realistic options, while vapor release and discharge into the sea, which have been performed elsewhere, are practical options.
- The government is expected to make a final decision based on the merits and demerits of vapor release and discharge into the sea while considering the opinions of diverse stakeholders, including the local community.
- Owing to its proven track record with conventional reactors, ease of handling of discharge equipment, and monitoring methods, the implementation of the discharge into the sea will be more reliable than vapor release.
- Tritium monitoring should be strengthened before and after the commencement of disposal by instituting more measuring locations and a higher frequency of measurements.

[Direction of Countermeasures against Reputational Damage]

- Possible measures against reputational damage include risk communication and economic measures to prevent, neutralize, and compensate for its occurrence. Proper measures need to be considered at the stages of consumption, distribution, and production, including overseas impact.
- In addition to the reputational damage that has already occurred, the disposal of ALPS treated water, etc. will most likely create additional economic impact, and measures to deal with further reputational damage—over and above those that have been taken to address it—are necessary.
- It is crucial to determine a disposal method that can minimize reputational damage and provide detailed and easy-to-understand information on secondary treatment, as well as data on concentrations in ALPS treated water, etc. to be disposed.
- Japan should utilize opportunities to disseminate related information to the international community, including neighboring countries, through avenues such as international conferences and briefings for Tokyo-based diplomatic missions and the foreign press.
- At the production stage, support is needed in the form of compensation. However, it is also necessary to support the local community to achieve self-reliance. At the distribution stage, support is required to solve structural problems, including those outside the prefecture, when necessary.

(Source) Prepared by the author based on 多核種除去設備等処理水の取扱いに関する小委員会「多核種除去設備等処理水の取扱いに関する小委員会報告書」2020.2.10 (Subcommittee on Handling of ALPS treated Water, "Report of the Subcommittee on Handling of ALPS treated Water," 2020.2.10).

Based on the findings and recommendations of the ALPS Subcommittee report, seven meetings were held by the government from April to October 2020 to solicit the views and opinions of stakeholders from various sectors, including municipalities, agriculture, forestry, fisheries, and commercial organizations. In addition to meetings, written submissions were invited.[110] Eventually, 4,011 written submissions were received by the government. Although the concerns raised in these submissions often overlapped one another, approximately 2,700 of them expressed concerns about the safety of discharging it into the sea, 1,000 were concerned about reputational effects and delays in reconstruction, and 1,400 expressed concerns about the consensus.[111]

In conjunction with the discussions held by the ALPS Subcommittee, various experts also offered their views and opinions on discharge into the sea, which are summarized in Table 5.

Table5 **Opinions of Major Experts**

[MIYANO Hiroshi, Chairman, Review Committee on Decommissioning of the Fukushima Daiichi Nuclear Power Station, Atomic Energy Society of Japan] • The only way to store debris safely is to build facilities on higher grounds where the tanks are located. • To proceed with decommissioning, a choice must be made to discharge the ALPS treated water into the sea and remove the tanks. Although a proposal to continue tank storage is being considered, the tanks are aging. Permanent storage is not a possible option, and continued storage will only postpone the problem. • Nuclear facilities that operate in Japan and overseas continue to release tritium into the sea and the atmosphere routinely. Although the amount of tritium stored at the Fukushima Daiichi NPP is approximately 1,000 trillion Bq, some overseas nuclear fuel reprocessing facilities release more than 1,500 Bq annually.
[OKAMOTO Koji, Professor, Graduate School of Engineering, The University of Tokyo] • Prior to discharge, treated water is subjected to another round of secondary treatment and only after a low concentration of radioactivity is found. Hence, its discharge into the sea will have no impact on the environment. When a choice is made to avoid discharge into the sea to prevent reputational damage, it will only worsen the damage. • Although the tanks used to store the treated water are made from durable stainless steel, they cannot be used for storage that last decades. In an unlikely event that a tank is damaged by an earthquake or there is a leakage, the contaminated water will remain on the site. Nevertheless, the reputational damage would be much worse. As the storage site for tanks will reach its capacity by the fall of 2022, decommissioning work may be halted.

[110] The following materials summarize the main opinions expressed at the "Forum for Hearing Opinions" and from written submissions. 廃炉・汚染水対策チーム事務局「多核種除去設備等処理水の取扱いに関する御意見について」（廃炉・汚染水対策チーム会合（第 6 回）資料 1）2020.10.23 (Secretariat of the Team for Countermeasures for Decommissioning and Contaminated Water Treatment, "Seeking Opinions on the Handling of ALPS treated Water," Measures for Decommissioning, Contaminated Water, Treated Water Task Force, Meeting No. 6, Document 1, 2020.10.23).

[111] *ibid.*, p.5.

[TAUCHI Hiroshi, Professor, College of Science, Ibaraki University]

- Exposure to tritium from the treated water at the Fukushima Daiichi NPP has virtually no impact on human health. However, as long as tritium is a radioactive material, one cannot certainly say that its impact would be zero, and it is an issue that can be difficult to address.

- Although the fishing industry in Fukushima is in the recovery phase, it is important to consider whether it is appropriate to dispose of the treated water now. After explaining the scientific properties of tritium to them, some people will still find the explanation too difficult to understand, and there will always be reputational damage regardless of where the water is released. It is necessary to discuss whether long-term storage should be continued until the agricultural, forestry, and fishery sectors of the economy in Fukushima have recovered.

[KOYAMA Ryota, Professor, Faculty of Food and Agricultural Sciences, Fukushima University]

- The strategy of persuading fisherfolk to accept discharge into the sea would create the impression that it was accepted by them, drawing criticism toward the local community. This point must be considered carefully from the perspective of local fishermen and those involved in the fishing industry. Again, it is necessary to clarify that the responsibility still lies with the government and TEPCO. Decommissioning work cannot progress at the expense of reconstruction. Policies cannot be made based on the assumption that people in the affected areas will continue to suffer and endure ten years after the earthquake and nuclear accident had occurred. To prevent this scenario from developing, it is important to be prepared to build a consensus with most stakeholders, including the people of Japan and neighboring countries, on an acceptable method of disposal.

[SEKIYA Naoya, Associate Professor, Interfaculty Initiative in Information Studies, The University of Tokyo]

- If disposal of ALPS treated water is initiated, it could aggravate reputational damage. It is important to manage its initial impact (on society). When more time has lapsed before disposal commences, its impact will be smaller. I believe that taking time may be the best measure to address the impact of reputational damage.
- Although ten years have elapsed since the Great East Japan Earthquake, fisheries and distributors in Fukushima are struggling to restore their sales and supply chains to Tokyo and other metropolitan areas, and the fishing industry is still in the early stages of recovery. If a decision on discharge into the sea is made at this time, it will have serious implications for investment and succession issues in the fishing industry.　Hence, a decision taken by the government to discuss the pros and cons of discharge into the sea at this time is a questionable move.

[Citizens' Commission on Nuclear Energy]

- Much opposition against discharge into the sea was voiced at public hearings convened by the Ministry of Economy, Trade and Industry and in municipal resolutions in Fukushima, appeals by fishery groups, and petitions by the general public. A decision to release the ALPS treated water into the sea should not be made by the government after ignoring these dissenting voices.
- Technologies that can address a preference for "onshore storage in large tanks" and "disposal by mortar solidification" are currently available. This would allow for long-term, responsible management and disposal of contaminated water on land.

(Note) The Citizens' Commission on Nuclear Energy is a specialized platform established to collect and analyze information and make recommendations on policies necessary to create a society free from nuclear energy based on lessons learned from the Fukushima Daiichi NPP accident. The Commission is chaired by OSHIMA Kenichi—a professor from the Faculty of Policy Science at Ryukoku University.

(Sources) Prepared by the author based on 「論点スペシャル　福島第一　増え続ける処理水」『読売新聞』2019.3.27 ("Special Issue: The Ever-increasing Treated Water at Fukushima Daiichi," *Yomimuri Shimbun*, 2019.3.27);「論点直言　福島第１原発　処理水どうする」『産経新聞』2021.3.14 ("Direct Comment: What to Do about the Fukushima Daiichi Treated Water?," *Sankei Shimbun*, 2021.3.14); 小山良太「海洋放出の是非を考えるのに欠かせない「トリチウム水」への理解」『論座』2020.7.8 (KOYAMA Ryota, "Understanding 'Tritium Water' Essential to Considering the Pros and Cons of Ocean Discharge," *Ronza*, 2020.7.8)>; 「【風評の深層・処理水の行方】処理水…宙に浮く「国民的議論」」『福島民友新聞』（電子版）2020.7.1 ("Depth of Rumors and the Future of Treated Water" Treated water … Unsettled Issue 'National Debate,'" *Fukushima Minyu Shimbun* [Online

Edition], 2020.7.1); 原子力市民委員会「声明：政府は福島第一原発 ALPS 処理汚染水を海洋放出してはならない　汚染水は陸上で長期にわたる責任ある管理・処分を行うべきである」2020.10.20 (Citizens' Commission on Nuclear Energy, "The Government Should Not Release the Fukushima Daiichi NPP ALPS treated Contaminated Water into the Sea: Contaminated Water Should Be Responsibly Managed and Disposed of on Land for the Long Term," 2020.10.20).

3 *Decision on Discharge into the Sea*

After six years of discussion by the Tritiated Water Task Force and the ALPS Subcommittee, which included hearings with municipalities and other stakeholders, the government decided on a Basic Policy for ALPS treated Water at a meeting of the Inter-Ministerial Council for Contaminated Water, Treated Water, and Decommissioning Issues[112] held on April 13, 2021. Under this policy, ALPS treated water that has been purified[113] and has a concentration of radioactive materials—other than tritium—below the regulatory limits (i.e., the sum of the ratios to the regulatory concentration limits was below 1) would be diluted with seawater by over 100 times before it is discharged into the sea (Table 6).[114]

After dilution, the concentration of tritium is benchmarked at the same level as the operational target (less than 1,500 Bq/L) for effluent concentrations in sub-drain wells, and the total permissible amount is less than 22 trillion Bq/year, which is similar to that for

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[112] On September 3, 2013, the government decided to establish an "Inter-Ministerial Council for Contaminated Water and Decommissioning Issues" under the Nuclear Emergency Response Headquarters in a comprehensive effort to provide a fundamental solution to the problems of decommissioning and contaminated water rather than leaving them to the operators to resolve on their own. This decision was made in conjunction with the introduction of the Basic Policy for the Contaminated Water Issue (Nuclear Emergency Response Headquarters, *op.cit.*. (21), p.7). On April 13, 2021, the name of the Council was changed to "The Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues" to prevent any reputational damage that may be caused by the confusion between contaminated and treated water. (原子力災害対策本部「廃炉・汚染水対策関係閣僚等会議等の名称の変更について」(廃炉・汚染水・処理水対策チーム会合／事務局会議（第 89 回）資料 1）2021.4.13 (Nuclear Emergency Response Headquarters, "Change of the Name of the Inter-Ministerial Council for Contaminated Water and Decommissioning Issues," Secretariat of the Team for Countermeasures for Decommissioning, Contaminated Water and Treated Water Meeting No. 89, Document 1, 2021.4.13).

[113] TEPCO intends to repeat purification treatment (secondary treatment) of water stored in tanks until the sum of the ratios to regulatory concentration limits of 62 nuclides (nuclides to be removed by ALPS)—other than tritium—and carbon-14 reaches below 1 at the pre-dilution stage. Since September 2020, TEPCO has been conducting performance verification tests for secondary treatment at ALPS and has verified the possibility of lowering the sum of the ratios to regulatory concentration limits of 62 nuclides and carbon-14 to below 1. 東京電力ホールディングス「多核種除去設備等処理水の処分に関する政府の基本方針を踏まえた当社の対応について」2021.4.16, pp.1, 3, 5 (TEPCO Holdings, "Response to the Government's Policy on the Handling of ALPS treated Water," 2021.4.16, pp.1, 3, 5).

[114] 廃炉・汚染水・処理水対策関係閣僚等会議　前掲注(4), pp.9-10 (Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues, *op.cit.*(4), pp.9-10).

discharge at the Fukushima Daiichi NPP before the accident.[115] Additionally, other than tritium, the sum of the ratios to regulatory concentration limits is under 0.01 after dilution. TEPCO is also required to obtain approval[116] from the Nuclear Regulation Authority in its design and operation of facilities[117] necessary for discharge into the sea, and it is expected that offshore release will be implemented in about two years.[118]

***Table6* Overview of the Basic Policy for ALPS treated Water**

[Reconstruction and Decommissioning] • Without a reexamination of the current situation—where the tanks and piping facilities used to store treated water occupied a large area of the site—future decommissioning work may be significantly impeded. • The tanks have been identified as a factor that contributed to the reputational damage caused by rumors, and their use for long-term storage increases the risk of deterioration and leakages due to disasters. • Local municipalities have expressed their belief that the national government should assume responsibility to decide on the measures as soon as possible without postponing a resolution of the fundamental problems. • To ensure that safe measures are taken during decommissioning work and in the management of contaminated and treated water, the government must determine a policy at an early stage to handle water stored in the tanks based on the overarching principle of "Balancing Reconstruction with Decommissioning."
[Disposal of ALPS treated Water] • Based on the findings of the ALPS Subcommittee and views of various stakeholders that included the public and to ensure the safe implementation of measures, smooth progress in decommissioning work, and handling of contaminated and treated water, the disposal of ALPS treated water will be performed in strict compliance with various laws and regulations, as well as with thorough measures to control its reputational impact. • Based on its proven track record in Japan and the reliability and stability that it offers in terms of implementation and monitoring capabilities, discharge into the sea has been selected as the disposal method.

[115] *ibid.*, p.9. TEPCO has assumed that the concentration of tritium is approximately 440 Bq/L after dilution. 東京電力ホールディングス「多核種除去設備等処理水の取扱いに関する検討状況【概要】」2021.8.25, p.4 (TEPCO Holdings, "Status of Review Regarding the Handling of ALPS treated Water [Summary]," 2021.8.25, p.4). The total amount is capped at 22 trillion Bq currently but will be revised according to the progress of decommissioning and a consideration of other factors. 東京電力ホールディングス　前掲注 (113), p.6 (TEPCO Holdings, *op.cit.*. (113), p.6).

[116] Specifically, TEPCO is required to obtain approval for amendment to the "Implementation Plan for Fukushima Daiichi Nuclear Power Station Specified Nuclear Facility" published on the website of TEPCO Holdings (the latest version is available).

[117] TEPCO has envisioned that the facilities will include three seawater transfer pumps for dilution and an undersea tunnel with an approximate length of 1 km to facilitate discharge into areas where fishing is not conducted daily. 東京電力ホールディングス　前掲注 (115), pp.4-5, 7 (TEPCO Holdings, *op.cit.*(115), pp.4-5, 7).

[118] Before initiating the necessary approval procedures from the Nuclear Regulation Authority, in the case of discharge into the sea, TEPCO will first evaluate the safety and effects of radiation on humans and the environment, and have them reviewed by experts from the IAEA and others. Second, one year prior to starting of disposal, TEPCO will expand and strengthen the monitoring of the sea area by measuring and evaluating tritium and cesium-137 and increasing the number of fish and seaweed samples tested for radioactive concentrations. 東京電力ホールディングス　前掲注(113), pp.6-8, 12 (TEPCO Holdings, *op.cit.*. (113), pp.6-8, 12).

• TEPCO must obtain approval from the Nuclear Regulation Authority for its detailed plan and installation of necessary equipment prior to discharge into the sea, which will begin after approximately two years.
[Specific Methods for Discharge into the Sea] • Analyze ALPS treated water for tritium concentration, verify that the concentration of radioactive materials—other than tritium—is below the regulatory limits prior to discharge into the sea, and publish this information. • Dilute ALPS treated water with seawater for 100 times or more until the tritium concentration reaches the same level (1/40th of the regulatory concentrations limits) as the operational target (less than 1,500 Bq/L) of effluent concentration in sub-drain wells of the Fukushima Daiichi NPP. After dilution, the sum of the ratios to regulatory concentration limits—other than tritium—must be less than 0.01. • The annual amount of tritium that can be released is lower than the operational standard value for discharge (22 trillion Bq/year) at the Fukushima Daiichi NPP before the accident, and it will be reviewed periodically. • To enhance objectivity and transparency, strengthen and expand monitoring capabilities through cooperation with the International Atomic Energy Agency, participation by agricultural, forestry, fishery, and local government officials, and organization of a conference with marine environment experts.
[Response to Reputational Effects] • Within Japan, disseminate science-based information to domestic consumers and businesses and engage in two-way communication with them. In terms of foreign policy, share information with other countries on the safety of discharge into the sea and an assurance that it is done according to established international practices. • Implement thorough measures at each stage of production, processing, distribution, and consumption to achieve a full-fledged recovery by the fisheries industry in Fukushima. Economic measures in areas such as tourism, commerce, agriculture, and forestry will be taken to promote growth and development, including mingling among people, migration and settlement, and sales of agricultural products. • When reputational damage occurs after all measures have been exhausted, TEPCO will be instructed to respond swiftly as a part of its compensation for the nuclear damage caused by the Fukushima Daiichi NPP accident.
[Issues for Future Consideration] • Although the development of technology to separate tritium has not reached a stage for practical use by the Fukushima Daiichi NPP, new technological trends will be closely monitored for feasible technologies that can be actively incorporated for practical use. • Efforts will continue to be made to minimize the amount of contaminated water being generated. Measures to lower the radioactivity levels in the harbor, such as cleaning drainage channels and removal of marine species from the harbor, will be implemented.

(Source) Prepared by the author based on 廃炉・汚染水・処理水対策関係閣僚等会議「東京電力ホールディングス株式会社福島第一原子力発電所における多核種除去設備等処理水の処分に関する基本方針」2021.4.13 (The Inter-Ministerial Council for Contaminated Water, Treated Water, and Decommissioning Issues, "Basic Policy on Handling of ALPS treated Water at the Tokyo Electric Power Company Holdings' Fukushima Daiichi Nuclear PowerStation," 2021.4.13).

The response to the Basic Policy for ALPS treated Water was mixed. Some experts opined that discharge into the sea "has no safety or technical problems, is the most suitable method," and "is a realistic option to minimize the risk."[119] However, others had criticized the consensus-building process that resulted in its decision—especially by fisherfolk—and

[119] 宮野広「安全面でも最適な方法」『日本経済新聞』2021.4.14 (MIYANO Hiroshi, "Optimal Method for Safety," *Nihon Keizai Shimbun*, 2021.4.14);「処理水放出　風評対策を議論」『読売新聞』2021.4.15 ("Release of Treated Water Discussion on Measures for Reputation," *Yomimuri Shimbun*, 2021.4.15).

its timing (shortly after the completion of trial operations in preparation for the resumption of full-scale fisheries operations[120]).[121] Some municipalities in Fukushima moved to pass opinions requesting the early presentation of measures against reputational damages or calling for a withdrawal of the policy for discharge into the sea.[122] Further, people involved in fisheries in Fukushima as well as in Miyagi and Ibaraki voiced their opposition to discharge into the sea in the absence of public understanding.[123]

IV Response to Reputational Damage

1 *Domestic Response*

Although the Fukushima Daiichi NPP accident occurred ten years ago, and consumers' aversion to foods produced in Fukushima Prefecture is declining, the wholesale prices of many agricultural products from Fukushima, have not recovered to levels seen before the Great East Japan Earthquake. For example, public perception of rice produced by the prefecture was extremely unfavorable after the nuclear accident. Consequently, it was treated as a low-ranking production area.[124] A survey conducted by the Ministry of

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120 From June 2012 until the end of March 2021, efforts were made to obtain basic information on the resumption of fishing operations in Fukushima by conducting test operations to assess the impact of rumors by launching small-scale operations and sales on a trial basis with a limited number of fish species. Since April 2021, fishing operations have gradually increased their catch to the pre-accident levels.

121 五十嵐泰正「東電・国に不信　風評の元」『朝日新聞』2021.5.11 (IGARASHI Yasumasa, "Source of Distrust and Rumors of TEPCO and the State," *Asahi Shimbun*, 2021.5.11); 和合亮一「「思い」分かち合う仕組みを」『毎日新聞』2021.5.14 (WAGOU Ryoichi, "A Mechanism for Sharing Thoughts," *Mainichi Shimbun*, 2021.5.14). In response to the government's policy decision, the National Federation of Fisheries Co-operative Associations also issued a statement by their chairperson, which stated, "The government had clearly responded to the request of the National Federation of Fisheries Co-operative Associations that it would not dispose of ALPS treated water without the understanding of the fisherfolk involved during the process of measures to deal with contaminated water. Why has it reversed its position? This decision tramples on the wishes of fisherfolk in Fukushima and throughout Japan." 岸宏「アルプス処理水海洋放出の方針決定に強く抗議する JF 全漁連会長声明」2020.4.13 (KISHI Hiroshi, "Statement by Chair of National Federation of Fisheries Co-operative Associations Strongly Protesting Against the Policy Decision of Discharging　ALPS treated Water into the Sea," 2020.4.13).

122 「原発事故処理水　福島県内 36 議会が政府の海水放出方針に懸念」『福島民報』(電子版) 2021.7.3 ("NPP Accident Treated Water: 36 Councils within Fukushima Concerned about Government's Policy for Discharge into the Sea," *Fukushima Minpo* [online edition], 2021.7.3).

123 「官製風評／処理水海洋放出　宮城、茨城にも危機感　自民復興加速化本部　意見聴取　風評長引きかねない　漁業関係者ら懸念の声」『福島民報』2021.6.3 ("Government-Manufactured Rumors/Treated Water Discharge into the Sea: Miyagi, Ibaraki also Feel Threatened, LDP Reconstruction Acceleration Headquarters Hear Opinions, Fishermen Voice Concerns that Rumors May Linger," *Fukushima Minpo*, 2021.6.3).

124 遠藤明子「福島県産農産物の風評被害の推移と市場課題―消費者意識と卸売段階の動向を中心に―」『復興』9, 2021.3, pp.53, 54, 56 (ENDO Akiko, "Trends in Reputational Damage

Agriculture, Forestry and Fisheries had revealed a gradual narrowing in the price difference between the agricultural and marine products from Fukushima and the rest of the country. The prices of some items—such as tomatoes, asparagus, French beans, flatfish, and flounder—have recovered to the same level as the rest of the country. However, the prices of many products—such as rice, peaches, dried persimmons, pears, apples, grapes, green onions, broccoli, green peas, fresh shiitake mushrooms, nameko mushrooms, beef, pork, skipjack tuna, and conger eel—are still below the national average.[125] While the problem immediately after the accident was of consumption, since many people would not purchase products from Fukushima due to anxiety (and chose products from other areas), experts believed that distribution became fixed over time, and even though people's sense of anxiety eventually resolved, recovering pre-disaster distribution channels has become an issue[126]

Nevertheless, environmental groups, citizen groups, and experts have expressed concerns about the discharge of ALPS treated water into the sea and its resultant effects, including exposure to OBT, possibility of bioaccumulation, and risk of genetic effects.[127] Although the government and TEPCO had posted articles and pamphlets on their respective websites to dispel the myths propagated on the harm that can be caused by the release of ALPS treated water into the sea, as well as the fact that nuclear facilities worldwide did not observe any ill effect associated with the discharge of tritium and discharge into the sea is also a safe method of disposal[128], their attempts failed to quell the concerns. Some had also

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of Agricultural Products from Fukushima and Market Issues: Focusing on Consumer Awareness and Trends at the Wholesale Level," *Reconstruction*, 9, 2021.3, pp.53, 54, 56).

125 農林水産省『「令和２年度福島県産農産物等流通実態調査」報告書概要』2021.3 (Ministry of Agriculture, Forestry and Fisheries, *FY 2020 Survey on Distribution of Agricultural Products from Fukushima Prefecture: Report Overview*, 2021.3).

126 Unlike before the Great East Japan Earthquake, rice, for example, is no longer sold in supermarkets, but is now used for commercial purposes. 関谷直也「第２講　風評被害の実態と対策」秋光信佳・溝口勝編『福島復興知学講義』東京大学出版会, 2021, pp.62-63, 72-73 (SEKIYA Naoya, "Lecture 2: Reputational Damage and Countermeasures," AKIMITSU Nobuyoshi and MIZOGUCHI Masaru, eds., *Lectures on Fukushima Reconstruction and Knowledge*, University of Tokyo Press, 2021, pp.62-63, 72-73).

127 ショーン・バーニー, 伴英幸原文監修『東電福島第一原発―汚染水の危機 2020―』2020.10, pp.16-18 (Shaun Burnie and BAN Hideyuki, eds., *Fukushima Nuclear Power Plant Contaminated Water Problem*, 2020.10, pp.16-18); 東京五輪の危険を訴える市民の会編著『東京五輪がもたらす危険―いまそこにある放射能と健康被害―』緑風出版, 2019, pp.58-66, 106-117 (Citizens' Group on the Dangers of Tokyo Olympics Compilation, "The Danger Posed by the Tokyo Olympics—Radiation and Health Damage There Now -," *Ryokufū Shuppan*, 2019, pp.58-66, 106-117); 西尾正道『被曝インフォデミック―トリチウム、内部被曝―ICRP によるエセ科学の拡散―』寿郎社, 2021, pp.105-126 (NISHIO Masamichi, "Radiation Exposure Infodemic—Tritium, Internal Exposure—Spread of Pseudocience by ICRP," *Jurousha*, 2021, pp. 105-126).

128 「安全・安心を第一に取り組む、福島の"汚染水"対策③トリチウムと「被ばく」を考える」2018.11.30 ("Putting Safety and Security First: Considering ③Tritium and Measures against Exposure to 'Contaminated water' in Fukushima," 2018.11.30); 経済産業省　「ALPS 処

criticized the fact that the total amount of radioactive materials, other than tritium, that remained after the completion of secondary treatment (i.e., purification treatment of water to be re-purified again using ALPS) was not disclosed.[129]

To prevent further reputational damage[130] that can result from the discharge of ALPS treated water into the sea, the government and TEPCO must enhance their credibility through thorough safety measures and highly transparent information disclosure[131], and take concrete measures to secure and expand distribution channels for marine products from the seas around Fukushima.

2 *Strengthening International Communication*

Although some countries—such as the US and member countries of the European Union—and the International Atomic Energy Agency had expressed an understanding of the policy for discharge into the sea, it was mainly met with concerns and criticisms by neighboring countries such as Russia, China, South Korea, and Taiwan (Table 7).

After the Fukushima Daiichi NPP accident, 55 countries and regions from across the world had imposed restrictions on the imports of foods and other products from Japan. As of September 22, 2021, 41 of them had removed these restrictions and attributed their removal to the measures taken by the Japanese government to address their concerns over the safety of the country's food exports. These included the establishment of a permissible

理水について（福島第一原子力発電所の廃炉対策）」2020.7 (Ministry of Economy, Trade and Industry, "On ALPS treated Water: Decommissioning Measures at Fukushima Daiichi Nuclear Power Plant," 2020.7); 復興庁「ALPS 処理水について知ってほしい 3 つのこと」(Reconstruction Agency, "Three Things You Need to Know About ALPS Treated Water"); 東京電力ホールディングス「「トリチウム」について」2021.4 (TEPCO Holdings, "Tritium," 2021.4).

129 国際環境 NGO FoE Japan「声明：処理汚染水の海洋放出決定に抗議する」2021.4.13 (FoE Japan, "Statement: Protest Against the Decision to Discharge Treated Contaminated Water into the Ocean," 2021.4.13).

130 Some have argued if the release of ALPS treated water discourages people from purchasing marine products that originate from the waters around the Pacific Ocean, their behavior is not motivated by "unfounded information" or "rumors" but by a "citizen's sense" of judgment based on scientific facts and should, therefore, be called "actual harm." 田中駿介「#汚染水の海洋放出決定に抗議します（上）―「風評被害」という言説で被害が隠されることを危惧する」『論座』2021.4.13 (TANAKA Shunsuke, "Protesting the Decision to Discharge Contaminated Water into the Sea: Part 1—Fear that the Damage Will be Concealed under the Discourse of 'Reputational Damage'," *Ronza*, 2021.4.13).

131 In 2018, several reports claimed that the government and TEPCO had increased mistrust and undermined the relationship of trust with the public after they failed proactively provide information even though they were aware that nuclides—other than tritium—remained above the regulatory limits after ALPS processing was completed. 「（社説）汚染水処理は丁寧な議論を」『日本経済新聞』2018.9.5 ("Editorial: Contaminated Water Treatment Needs Careful Discussion," *Nihon Keizai Shimbun*, 2018.9.5); 「（社説）福島の汚染水 「問題隠し」は許されぬ」『朝日新聞』2018.10.5 ("Editorial: Fukushima Contaminated Water 'Hiding the Problem' is Unacceptable," *Asahi Shimbun*, 2018.10.5).

level of radioactive materials that can be found in its food products, regular food inspections, and cessation of exports when this level is exceeded.[132] Nevertheless, there are concerns that the implementation of a policy for discharge into the sea might prompt some countries to reimpose their import restrictions on Japanese food products.[133]

***Table7* Reactions of Overseas Countries to the Basic Policy for ALPS treated Water**

Country/Organization	Response
International Atomic Energy Agency (IAEA)	A video message was published by its Director General who welcomed the announcement of Japan's decision and stated that the method of disposal chosen by the Japanese government was technically feasible and in line with international practice and that controlled discharges into the sea were routinely performed under regulatory approval by nuclear power plants worldwide. (4/13)
US	The State Department issued a statement that recognized that "in this unique and challenging situation, Japan has weighed the options and effects, has been transparent about its decisions, and appears to have adopted an approach in accordance with globally accepted nuclear safety standards. We look forward to the GOJ's continued coordination and communication as it monitors the effectiveness of this approach." (4/12)
European Union (EU)	At a press conference, a spokesperson for the EU stated, "it is important that full transparency is provided in the proceedings" and "we hope that national and international obligations are fulfilled, and adequate security is ensured." (4/13)
Russia	The Ministry of Foreign Affairs issued a statement by saying that it is "regrettable that Japan did not consider it necessary to consult with neighboring countries, including Russia (in advance)." It also criticized the Japanese government for its lack of sufficient disclosure of information, including a risk assessment to the environment. Further, it demanded that the Russian government should be allowed to conduct monitoring surveys in the sea area where the treated water is released. (4/13)
China	The Ministry of Foreign Affairs stated, "Despite domestic and international doubts and opposition, Japan has unilaterally decided to discharge contaminated water from the Fukushima nuclear power plant into the sea without adequate consultation with neighboring countries and the international community before exhausting safe disposal methods. This is a highly irresponsible act that will seriously affect human health and the immediate interests of people in neighboring countries." (4/13)
South Korea	The government expressed strong regret, criticizing the "unilateral measures" and emphasizing its "plan to take all necessary measures with the safety of the people as the top priority principle." (4/13) The National Assembly also adopted a resolution that strongly denounced the Japanese government's unilateral decision to discharge contaminated water into the sea and urged the government to withdraw its decision immediately. (6/29)

132 外務省ほか「米国の日本産食品に対する放射性物質規制の撤廃」2021.9 (Ministry of Foreign Affairs, "Elimination of US Restrictions on Radioactive Substances in Japanese Foods," 2021.9).

133 「処理水放出、海外向け情報発信急務　風評「逆輸入」の構図も」『河北新報』（電子版）2021.5.10 ("Release of Treated Water, Urgent Need to Disseminate Information to Foreign Countries, and the Structure of 'Reverse Import' of Rumor," *Kahoku Shimpo* [online edition], 2021.5.10).

North Korea	In a comment, the Korean Central News Agency condemned the discharge as an “unforgivable crime that seriously threatens the health and safety of mankind and the ecological environment” and demanded its immediate reversal by stressing that “the discharge of contaminated water by Japan is a serious problem concerning the safety of the lives of our people.” (4/15)
Taiwan	The Atomic Energy Council expressed regret and requested the Japanese government to strengthen technical exchanges and information sharing on the measurement of radioactive materials in the high seas near Taiwan and the monitoring and evaluation of the ocean between Japan and Taiwan. (4/13) The Executive Yuan has stated that no decision should be made until the people of surrounding countries were reassured and their safety was ensured. (4/14)
Pacific Islands Forum (PIF)	The Secretary General expressed deep concern about Japan’s decision to discharge ALPS treated water and “urgently called on the Government of Japan to hold off the conduct of the discharge of ALPS Treated Water until further consultations are undertaken with Pacific Island Forum Members and an independent expert review is undertaken to the satisfaction of all our Members.” (4/13)
Federated States of Micronesia (FSM)	The President sent a letter to Japanese Prime Minister Yoshihide Suga stating that, in addition to responding to the PIF’s request to conduct the review, a formal, multilateral dialogue with countries whose livelihoods depend heavily on the health of the Pacific Ocean would be extremely beneficial and would demonstrate close friendship and cooperation. (4/26)
Republic of the Marshall Islands (RMI)	The government issued a statement calling on Japan to consult with neighboring island nations and conduct an independent review of the potential impact of treating 1 million tons of contaminated water. (5/8)

(Sources) Prepared by the author based on the International Atomic Energy Agency, “IAEA Ready to Support Japan on Fukushima Water Disposal, Director General Grossi Says,” 2021.4.13; US Department of State, “Government of Japan’s Announcement on Fukushima Treated Water Release Decision,” 2021.4.12; 「原発処理水の海洋放出「透明性が重要」＝EU」『時事通信ニュース』2021.4.13 (“Discharge of Treated Water from Nuclear Power Plants into the Sea: ‘Transparency is Important’—EU,” *Jiji Press News*, 2021.4.13); 「ロシアが処理水海洋放出を批判　「協議なく残念」」『朝日新聞デジタル』2021.4.14 (“Russia Criticizes Discharge of Treated Water into the Sea: Lack of Consultation Regrettable,” *Asahi Shimbun Digital*, 2021.4.14); Ministry of Foreign Affairs, People’s Republic of China, “Foreign Ministry Spokesperson Zhao Lijian’s Regular Press Conference on April 13, 2021,” 2021.4.13>; 「韓国政府、日本福島汚染水の放流に「一方的な措置…強い遺憾」」『中央日報日本語版』2021.4.13 (“South Korean Government ‘Strongly Regrets ... Unilateral Measures’ Taken by Japan for the Discharge of Contaminated Water,” *JoongAng Ilbo Japanese Language Edition*, 2021.4.13); 「韓国国会、福島汚染水の海洋放出糾弾決議案を採択」『中央日報日本語版』2021.6.30 (“South Korean National Assembly Adopts Resolution Denouncing Discharge of Fukushima Contaminated Water into the Sea,” *JoongAng Ilbo Japanese Language Edition*, 2021.6.30); 「北朝鮮も海洋放出を非難＝原発処理水」『時事通信ニュース』2021.4.15 (“North Korea Also Condemns Ocean Release of Treated Water from Nuclear Power Plant,” *Jiji Press News*, 2021.4.15); 「福島第 1 原発処理水の海洋放出決定　台湾原子力委員会が遺憾を表明」『フォーカス台湾』2021.4.13 (“Taiwan Atomic Energy Council Expresses Regret over the Decision to Discharge Treated Water from Fukushima Daiichi Nuclear Power Plant into the Ocean,” *Focus Taiwan*, 2021.4.13); 「福島原発の処理水放出　行政院「安全確保まで決定すべきでない」／台湾」『フォーカス台湾』2021.4.14 (“Discharge of Treated Water from Fukushima Nuclear Power Plant—Executive Yuan: ‘No Decision Should be Made Until Safety is Ensured’,’” *Focus Taiwan*, 2021.4.14); Pacific Islands Forum, “Statement by Dame Meg Taylor, Secretary General of the Pacific Islands Forum, Regarding the Japan Decision to Release ALPS treated Water into the Pacific Ocean,” 2021.4.13; Federal States of Micronesia, “Regarding Japan’s Plans to Deposit Contaminated Water from Fukushima into the Ocean, President Panuelo Submits FSM’s Opposition, and Encourages Japan to Consider Hosting a Formal, Multilateral Dialogue with the Pacific,” 2021.4.27; Republic of the Marshall Islands, “RMI Conveys Concerns on Japanese Government Decision to Discharge Wastewater from Fukushima Daiichi Nuclear Power Station,” 2021.5.8.

As of September 22, 2021, the import restrictions imposed on Japanese products by 14 countries and regions—including China, South Korea, and Taiwan—were still in force after they expressed concerns about the decision on discharging into the sea made by Japan.[134] In Taiwan, the rumors and prejudices that surrounded the current situation in Fukushima Prefecture have persisted, and a referendum held in 2018 revealed that most Taiwanese were in favor of continuing the restrictions imposed on Japanese imports.[135] In South Korea, its government has continued to ban the imports of marine products from eight prefectures near Fukushima[136] and has indicated that it will consider a total ban on Japanese marine products after the implementation of discharge into the sea.[137] However, some experts in South Korea have expressed difficulty in finding concrete evidence, data, and information on why discharge into the sea was chosen, and how the effects on human health and the environment were evaluated.[138]

As some of these countries—especially China, South Korea, and Taiwan—are major destinations for Japanese marine exports[139], it will be necessary to provide more information, including scientific explanations, on the discharging ALPS treated water into the sea.

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134 In addition to China, Taiwan, and South Korea, five other countries and regions, including Hong Kong and Macau, have stopped importing food and other products from certain prefectures that include Fukushima Prefecture. Moreover, nine countries and regions (EU, UK, EFTA [Iceland, Norway, Switzerland, and Liechtenstein], French Polynesia, Russia, and Indonesia) have made it a requirement for some or all prefectures to issue safety inspection certificates for their products. 外務省ほか　前掲注(132) (Ministry of Foreign Affairs, *op.cit.* (132)).

135 謝牧謙「福島等 5 県産食品禁輸継続中の台湾の事情」『交流』955, 2020.10, pp.9, 10, 13 (SHIEH Mu-Chang, "Taiwan's Ongoing Embargo on Food Products from Fukushima and Five Other Prefectures," *Koryu*, 955, 2020.10, pp.9, 10, 13).

136 After South Korea imposed restrictions on the imports of seafood products from Japan, the Japanese government invoked the World Trade Organization (WTO) Agreement by requesting the establishment of a panel to investigate the matter. In February 2018, the panel found that South Korea had violated the WTO Agreement. However, in April 2019, a higher-level panel rescinded the earlier finding, and the dispute remains unresolved. 経済産業省通商政策局編『不公正貿易報告書―WTO 協定及び経済連携協定・投資協定から見た主要国の貿易政策―2021 年版』[2021], p.119 (Trade Policy Bureau, Ministry of Economy, Trade and Industry, ed., *Unfair Trade Report—Trade Policy of Major Countries from the Perspective of WTO Agreements and Economic Partnership Agreements and Investment Agreements, 2021 Edition*, 2021, p.119).

137 「[Q&A] 「日本放射能汚染水放出時は水産物輸入禁止も検討」＝韓国」『中央日報』2021.4.14 ("[Q&A] South Korean Government Considers Banning Seafood Imports in Case of Japan's Radioactive Water Release = South Korea," *JoongAng Ilbo*, 2021.4.14).

138 オ・チョルウ「信頼ではなく不信感招いた日本政府のトリチウム「キャラ化」」『ハンギョレ』2021.4.21 (Cheo-Woo Oh "Japanese Government's 'Characterization' of Tritium Caused Mistrust, Not Trust," *Hankyoreh*, 2021.4.21).

139 For the year 2020, in order of export value, marine products were exported by Japan to the following countries: Hong Kong, China, the US, Thailand, Taiwan, Vietnam, and South Korea. 『令和 2 年度水産の動向　令和 3 年度水産施策』(第 204 回国会（常会）提出) 2021, p.73 (*Trends in Fisheries in FY 202020: Fisheries Policy for FY 2021*, submitted to the 204th National Diet Ordinary Session, 2021. p.73).

3 *Compensation*

Under the Basic Policy for ALPS treated Water, besides the dissemination of domestic and international information by the government, it will take measures to promote a full-fledged recovery by various sectors of the economy, including the fisheries trade, tourism and commerce, agriculture, and forestry. In the event that reputational damage still occurs after all measures have been exhausted, the government will instruct TEPCO to provide compensation as a part of the compensation for nuclear damage caused by the Fukushima Daiichi NPP accident.[140]

Currently, the most expeditious way for a victim to be awarded compensation by TEPCO is to file a claim with the company directly. The claim will be assessed by TEPCO—the perpetrator—based on the guidelines of the Dispute Reconciliation Committee for Nuclear Damage Compensation. After the assessment is completed, the company will unilaterally present the details of the claim and amount of compensation. However, it was reported that the details and amount offered do not fully reflect the extent of actual damage.[141] When no compensation is made after a claim has been lodged with TEPCO, or if the amount of compensation offered by the company is deemed unsatisfactory, the victims can approach the Nuclear Damage Compensation Dispute Resolution Center (hereafter referred to as "the Center")[142] for assistance with mediation to reach a settlement, which is a far more simple and faster method of adjudication than a court trial. Nevertheless, the proceedings tend to be protracted.[143] Additionally, there were cases where no settlement was reached after TEPCO refused to accept an offer proposed by the Center to

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140 Inter-Ministerial Council for Contaminated Water, Treated Water and Decommissioning Issues, *op.cit...* (4), pp.13-14.

141 除本理史「第 8 章　賠償の問題点と被害者集団訴訟」丹波史紀・清水晶紀編著『ふくしま原子力災害からの複線型復興―一人ひとりの生活再建と「尊厳」の回復に向けて―』ミネルヴァ書房, 2019, p.248 (YOKEMOTO Masafumi, "Chapter 8: Compensation Issues and Victims' Class Action Lawsuits," TAMBA Fuminori and AKINORI Shimizu, eds., *Fukushima Compounding Reconstruction from Nuclear Disaster—Toward Reconstruction of Each Individual's Life and Restoration of "Dignity,"* Minerva Shobo, 2019, p.248).

142 In response to the accidents that occurred at the Fukushima Daiichi and Daini Nuclear Power Plants, the Dispute Reconciliation Committee for Nuclear Damage Compensation was established in April 2011 by the Ministry of Education, Culture, Sports, Science and Technology under Article 18 of the "Act on Compensation for Nuclear Damage" (Act No. 147 of 1961). The committee is tasked with performing duties related to the mediation and settlement of disputes that had arisen over the compensation for nuclear damage caused by the accidents. 「原子力損害賠償紛争解決センター組織規程」文部科学省ウェブサイト ("Rule for the Organization of the Nuclear Damage Compensation Dispute Resolution Center.").

143 In 2014, the average waiting time between the appointment of mediators and presentation of a settlement proposal was 4.6 months. However, the wait has lengthened over the years to 11.0 months in 2019. In 2020, the average waiting time was 10.0 months, a month shorter than that in the previous year. 原子力損害賠償紛争解決センター「原子力損害賠償紛争解決センター活動状況報告書～令和 2 年における状況について～（概況報告と総括）」2021.3, p.18 . 同上 (Center for Nuclear Damage Dispute Resolution, "Report on the Activities of the Center for Nuclear Damage Dispute Resolution—Status in 2020: Summary Report and Summary," 2021.3, p.18. *ibid.*)

resolve the dispute.[144]

Moreover, claimants who are dissatisfied with TEPCO's decision on their applications for compensation may be forced to claim and prove their damages in other ways, such as through lawsuits, which may delay early relief. Consequently, there are calls on the government and TEPCO to take a more careful and sympathetic approach toward the accident victims.[145]

Conclusion

Although tritium is released into the seas from across the world regularly, the attempt made by Japan is viewed as unprecedented. This is because it aims to use a special and complex process to purify and dispose of a large amount of contaminated water generated after contact was made with melted nuclear fuel (fuel debris) in a large-scale core meltdown accident.[146] A complete and thorough understanding of the necessity and safety of this process and method of disposal by the Japanese people and the international community cannot be easily addressed. Consequently, doubts and objections to the policies taken by the Japanese government and TEPCO are expected to persist. Although the government has compiled a list of measures that should be urgently implemented[147] based on the Basic Policy for ALPS treated Water, it is expected that they will be developed more effectively to avoid suppressing the recovery process at an early stage.

To provide a fundamental solution to the issue of contaminated water, it is necessary

[144] From 2014 to 2020, of the 19,163 ADR cases lodged with the ADR concerning nuclear power plants, 1,527 cases were closed. Of these, the respondent rejected settlement offers in 129 cases, which included 75 cases filed by TEPCO employees or their family members. (*ibid.*, p.15).

[145] "Verification: Fukushima Daiichi Nuclear Power Plant Treated Water, Government-Manufactured Rumors, Ocean Discharge of Treated Water, No Expectation of Appropriate Compensation," interview with Professor YOKEMOTO Masafumi, Graduate School of Business Administration, Osaka City University, "A Mechanism to Satisfy Victims." 『福島民報』 2021.4.18 (*Fukushima Minpo*, 2021.4.18).

[146] After the nuclear accident that occurred on Three Mile Island, contaminated water that contained tritium was evaporated by boilers and released into the atmosphere as steam. It took more than two years to release approximately 8,700 m^3 of contaminated water and 24 trillion Bq of tritium. 多核種除去設備等処理水の取扱いに関する小委員会　前掲注(107), p.19 (Subcommittee on the Handling of Treated Water for Polynuclear Species Removal Equipment, *op.cit.*(107), p.19).

[147] For example, to cope with a fall in demand for domestic and foreign marine products in Japan and by overseas countries after the release of ALPS treated water into the sea, new emergency measures that can be flexibly and efficiently implemented would be introduced nationwide. These include the establishment of a fund that can finance the temporary purchase and storage of fish products that can be frozen and an expansion of sales channels for those products that cannot be stored and frozen. ALPS 処理水の処分に関する基本方針の着実な実行に向けた関係閣僚等会議「東京電力ホールディングス株式会社福島第一原子力発電所における ALPS 処理水の処分に伴う当面の対策の取りまとめ」2021.8.24 (Inter-Ministerial Council Concerning the Continuous Implementation of the Basic Policy on Handling of ALPS Treated Water, "Summary of Immediate Measures for Disposal of ALPS Water at TEPCO Holdings, Inc.," 2021.8.24).

to ensure that it is not generated in the first place. However, more than 10 years after the Fukushima Daiichi NPP accident, the Japanese government and TEPCO have not been able to clearly show the way forward.[148] In the mid to longer term, there is a need to deal with the waste being generated from the treatment of contaminated water (secondary waste from water treatment[149]). It is expected that a realistic and concrete roadmap can be drawn up as soon as possible—one based on a comprehensive and long-term perspective by drawing on the collective wisdom of Japan and the international community.

YAMAGUCHI Satoshi, *Problems of Discharging ALPS Treated Water from the Fukushima Daiichi Nuclear Power Station into the Sea,* (Research Materials), 2023e-2, Tokyo: Research and Legislative Reference Bureau, National Diet Library, 2023 (Translated from *The Reference*, No. 850, 2021.10, pp. 97-121.).

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[148] In the mid-and-long-term roadmap, a goal of the government and TEPCO is to reduce the amount of contaminated water being generated to less than 100 m^3/day for average rainfall by 2025. 廃炉・汚染水対策関係閣僚等会議「東京電力ホールディングス（株）福島第一原子力発電所の廃止措置等に向けた中長期ロードマップ」前掲注 (39) pp.14-15 (Inter-Ministerial Council for Contaminated Water and Decommissioning issues, “The Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Station,” *op.cit...* (39), pp.14-15). To achieve this goal, TEPCO aims to prevent the inflow of rainwater and groundwater by repairing the roofs of the structures and ground surface around the reactor buildings. Beyond that, no specific goals or plans are provided. 東京電力ホールディングス「福島第一原子力発電所の汚染水処理対策の課題と対応」(汚染水処理対策委員会（第 23 回）資料 4）2021.6.25, p.23 (TEPCO Holdings, “Challenges and Responses to Measures for Contaminated Water Treatment at Fukushima Daiichi Nuclear Power Plant,” Committee on Countermeasures for Contaminated Water Treatment, Meeting No. 23, Document 4, 2021.6.25, p.23)). Among the current measures, in March 2018, the Committee on Countermeasures for Contaminated Water Treatment estimated that, except for some deep areas, the frozen soil wall can reduce contaminated water by 95 m^3 a day after its construction is completed. 汚染水処理対策委員会「凍土壁の評価と今後の汚染水対策について」2018.3.7, p.7. 同 (Committee on Countermeasures for Contaminated Water Treatment, “Evaluation of the Frozen Soil Wall and Future Measures for Contaminated Water,” 2018.3.7, p.7). *ibid.* <https://www.meti.go.jp/earthquake/nuclear/osensuitaisaku/committtee/osensuisyori/2018/pdf/020_s04_00.pdf>. However, in terms of its cost-effectiveness, there is some discussion on whether the frozen soil wall should be continued. 特定原子力施設監視・評価検討会「第 78 回会合議事録」2020.2.17, pp.14-16, 91-92 (“Proceedings of the 78th Meeting of the Commission on Supervision and Evaluation of the Specified Nuclear Facilities,” 2020.2.17, pp.14-16, 91-92).

[149] In addition to the treated water generated, the treatment of contaminated water produces three other types of waste products: adsorption towers, waste sludge (decontamination equipment sludge), and concentrated liquid waste slurry. An urgent issue that needs to be addressed is how these waste products can be safely stored through volume reduction, stabilization treatment, and an elimination of temporary outdoor storage. 東京電力ホールディングス「東京電力ホールディングス（株）福島第一原子力発電所の固体廃棄物の保管管理計画　2021 年 7 月版」pp.11–12 (TEPCO Holdings, “TEPCO Holdings, Inc.: Solid Waste Storage and Management Plan for Fukushima Daiichi Nuclear Power Station, July 2021 Version,” pp.11–12). Ultimately, it is necessary to consider how to treat and dispose of these waste products with other solid wastes such as rubble, felled trees, etc., and used protective clothing.