CNIC BRIEF

Fukushima Daiichi Nuclear Power Station is Still Continuing to Release Radioactive Materials

A new argument for considering the issue of contaminated ALPS water release

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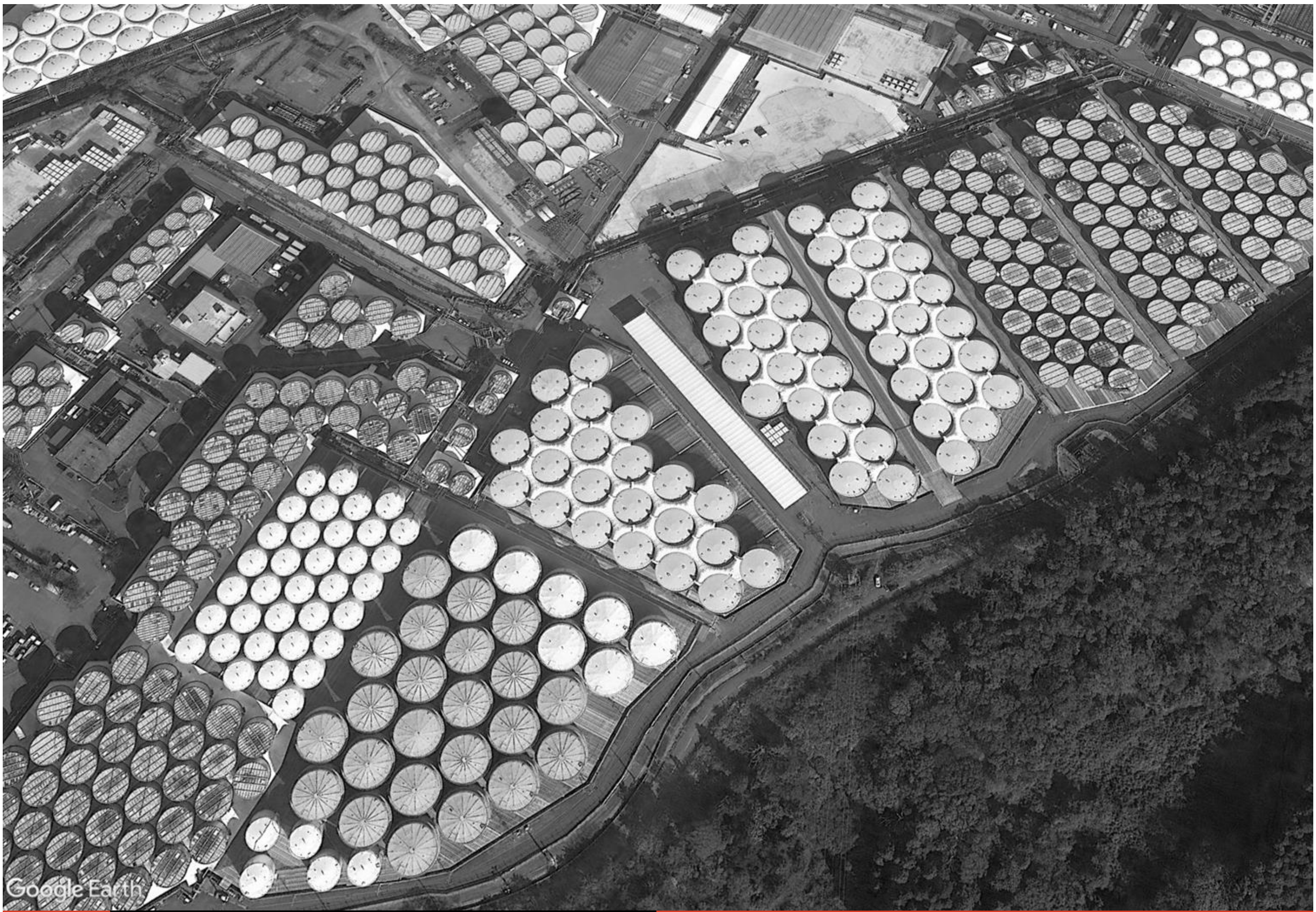


OVERVIEW

Explanations about the release of ALPS-treated contaminated water into the ocean have focused on tritium, stating that there is no effect and that the release is small compared to that of nuclear-related facilities in other countries. However, as of May 2023, an estimated 7 billion to 9.6 billion Bq/month of cesium-137, 250 billion to 290 billion Bq/month of total β-ray, and 43 billion to 53 billion Bq/month of tritium are leaking from the Fukushima Daiichi Nuclear Power Station (FDNPS) to the dedicated port.

Planned releases of radioactive materials in ALPS-treated contaminated water include 4 million Bq/month of cesium-137, 2.8 billion Bq/month of total beta, and 1.8 trillion Bq/month of tritium. If we focus on radioactive materials other than tritium, it is clear that an overwhelmingly large amount of these materials is currently leaking out. Looking at cesium-137, for example, the leakage is 1,750 to 2,400 times greater than that contained in ALPS-treated contaminated water.

Extremely large amounts of radioactive materials have already been released from FDNPS, and the reality is that radioactive materials are still leaking out even 12 years after the accident. At the same time, ALPS-treated contaminated water is under the control of Tokyo Electric Power Company (TEPCO). In the face of uncontrollable radioactive releases, it is naturally the duty of TEPCO, the owner of FDNPS and the company inflicting the damage, to minimize the amount of radioactive material released to the outside world.

Any explanation suggesting that no radioactive materials other than ALPS-treated contaminated water are being released is misleading the public about the grim situation at FDNPS.

INTRODUCTION

Focusing on the amount of tritium contained in the problematic release of ALPS-treated contaminated water resulting from the nuclear accident at TEPCO's FDNPS, the Japanese government and the media have frequently asserted that the release is smaller than those from nuclear power plants (NPPs) in other countries*1. While it is true that such comparisons can be made if one looks only at the tritium in the ALPS-treated contaminated water, there are two major omissions here. One is that the ALPS-treated contaminated water contains a variety of nuclides other than tritium, and the other is that the Fukushima Daiichi plant is also releasing radioactive material through other routes.

The main pathways through which radiation is currently being released from FDNPS are: (1) leaks from buildings into the atmosphere, (2) releases associated with discharged groundwater after being pumped from subdrains, the groundwater bypasses, etc., and (3) leaks associated with groundwater and rainwater streams flowing into the dedicated port. Of these, TEPCO has evaluated the amounts released in (1) and (2), and although TEPCO is measuring the concentration of radioactive materials in the port, it has not estimated the amount being released by (3). The following is an estimate of the amount of radioactive materials currently being released from FDNPS.

LEAKS FROM BUILDINGS INTO THE ATMOSPHERE

TEPCO issues monthly estimates of additional leakages from FDNPS buildings. Radioactive cesium is what is being assessed, and as of May 2023, the leakage was estimated to be less than 10,000 becquerels per hour (Bq/h). Converting to months and years, this would be 7.2 million Bq/month and 87.6 million Bq/year. Noble gases have also been detected but excluded from the assessment because the radiation exposure dose is smaller than that of cesium.

Further, while leakages have decreased recently, there is concern that they will increase significantly in the future when operations such as removing fuel debris and demolishing buildings begin.

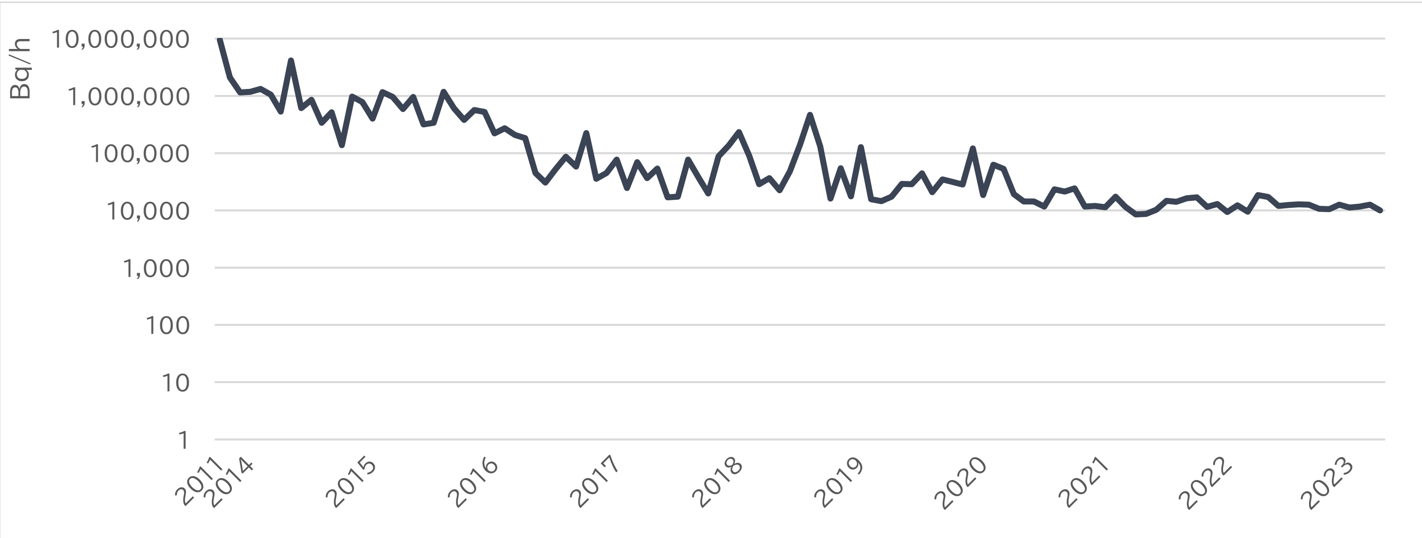


Figure 1. Estimate of Radioactive Cesium Releases to the Atmosphere from FDNPS Units 1-4 (per hour)
https://www.tepco.co.jp/decommission/information/newsrelease/emission/index-j.html

[1] https://www.env.go.jp/chemi/rhm/r4kisoshiryo/r4kiso-06-03-09.html, https://www.cn.emb-japan.go.jp/itpr_zh/00_000485_00225.html, https://www.yomiuri.co.jp/world/20230622-OYT1T50205/

DISCHARGES FROM GROUNDWATER BYPASSES, SUBDRAINS, etc.

To reduce groundwater inflow to the buildings at FDNPS, groundwater is pumped from groundwater bypasses in the area upstream from the buildings and then drained to a location outside the dedicated port after measuring radiation levels. For the same purpose, groundwater from sub-drains close to the buildings and groundwater drains on the port side is pumped up, treated, and drained into the dedicated port after measuring radiation levels.

Discharges of groundwater pumped from groundwater bypasses began in May 2014, and as of July 13, 2023, 485 discharges, totaling 832,496 tons, had been carried out. Discharges totaling 6,610 tons were conducted four times in June 2023, the amount of tritium contained in the discharges totaling 340 million Bq. Assuming discharges are continued in this way, annual discharges would amount to 4.08 billion Bq.

Discharges of groundwater pumped from subdrains and other sources began in September 2015, and as of July 12, 2023, 2,205 discharges, totaling 1,532,244 tons, had been carried out. Discharges totaling 19,229 tons were conducted 28 times in June 2023, the amount of tritium contained in the discharges totaling 15.34 billion Bq. Assuming discharges are continued in this way, annual discharges would amount to 194.08 billion Bq.

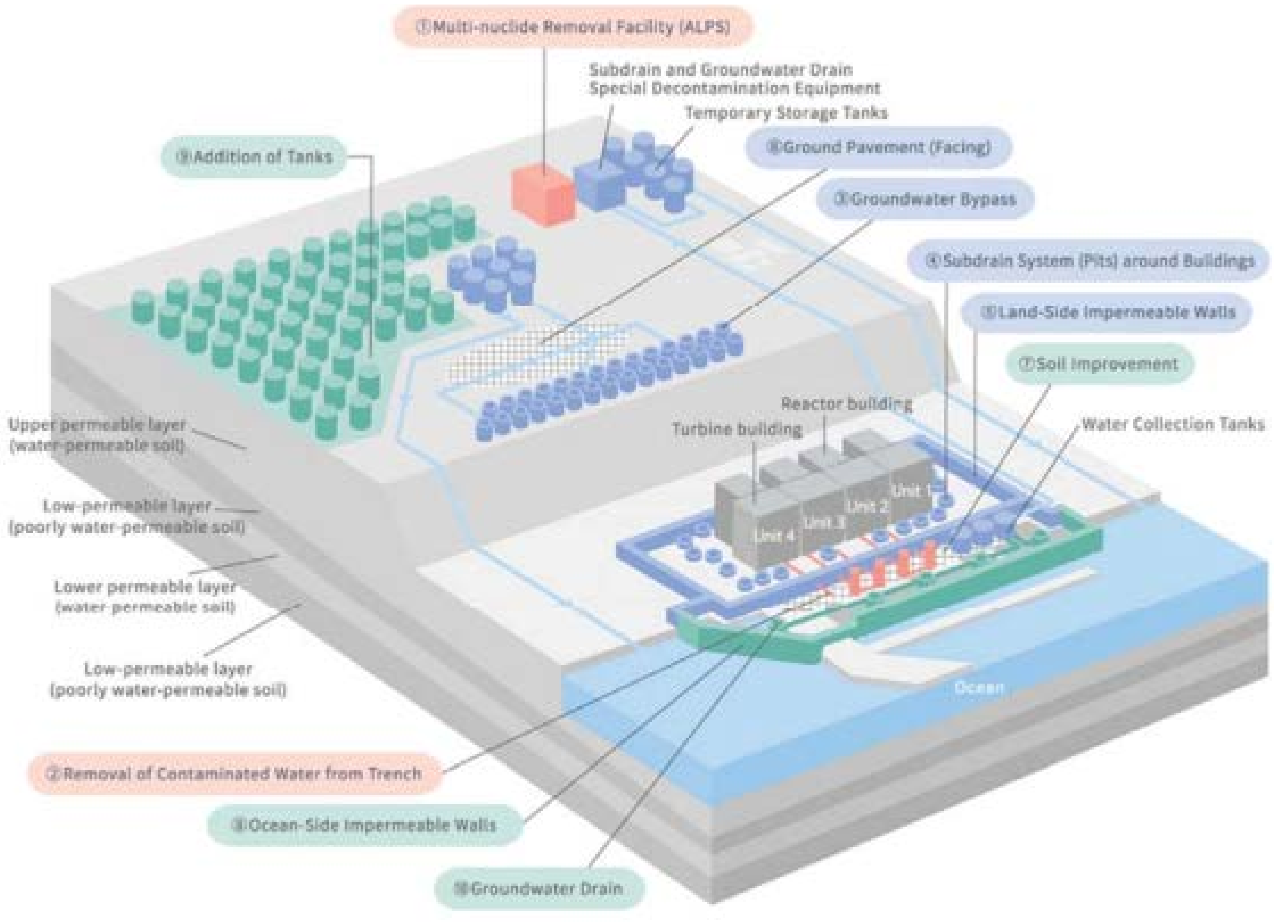


Figure 2. Concept Diagram of Occurrence of Contaminated Water at FDNPS (Source: TEPCO website)

LEAKS ASSOCIATED WITH GROUNDWATER AND RAINWATER STREAMS FLOWING INTO THE DEDICATED PORT

Groundwater flowing into buildings, etc. is causing an increase in the amount of contaminated water at FDNPS. Groundwater inflow is regulated by the land-side water barrier (the so-called frozen soil barrier) and subdrain groundwater pumping, but some water, including rainfall, flows seaward of the land-side water barrier.

TEPCO estimates the amount of runoff to be 20 to 60 m3 per day (November 2018 to March 2019). TEPCO has not disclosed current estimates, but the amount of groundwater, rainwater and other inflows into buildings has not changed significantly since 2018.

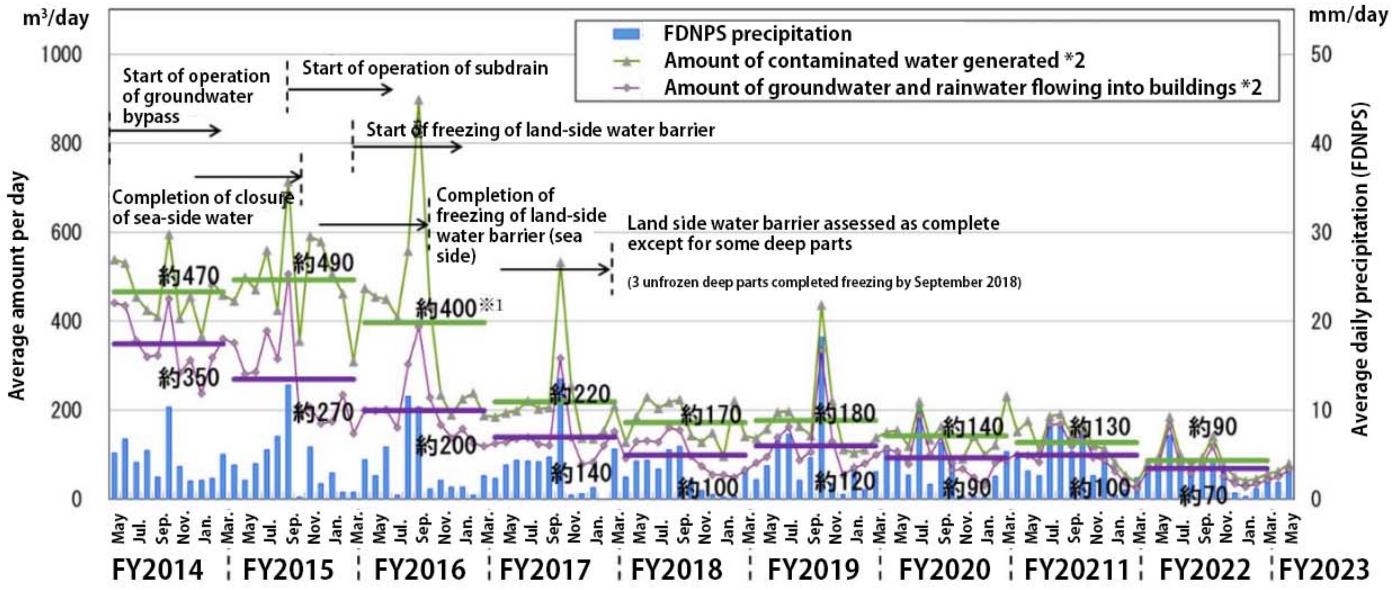
(Ref.) Assessment of Water Balance of Sea Side of the Frozen Soil Barrier (T.P.+2.5m base) Prior to Start of Freezing and Current State TEPCO

- Comparing the water balance of the sea side of the frozen soil barrier (T.P.+2.5m base) prior to the start of freezing and the current state, while there was a temporary increase in groundwater flow to the sea side of the frozen soil barrier, overall, there has been a large decrease compared to before the frozen soil barrier was operating.
- The decrease is thought to be the effect of multiple factors, such as prevention of permeation of rainwater (facing, etc.), operation of subdrains, and closure of the (sea side of the) frozen soil barrier.

Actual Values (m3/day)	(Ref.) Precipitation	Amount of Flow C	(1)	(2)	(3)	(4)	(5)
Jan. 1 to Mar. 31, 2016	1.4 mm/d	310	-40	80	240	50	-20
Jan. 1 to Mar. 31, 2018	2.4 mm/d	50	-40	10	50	30	0
Nov. 1 to Nov. 30, 2018	1.0mm/d	60	-20	10	60	30	-20
Dec. 1 to Dec. 31, 2018	0.5mm/d	50	-10	10	30	30	-10
Jan. 1 to Jan. 31, 2019	0.2mm/d	50	0	10	10	30	0
Feb. 1 to Feb. 28, 2019	0.3mm/d	40	0	10	10	30	-10
(Ref.) Mar. 1 to Mar. 20, 2019	4.4mm/d	20	-80	10	30	30	30

Figure 3. Amounts of Groundwater, etc. Flowing to the Sea Side of the Frozen Soil Barrier at FDNPS

https://www.meti.go.jp/earthquake/nuclear/decommissioning/committee/osensuitaisakuteam/2019/03/3-1-8.pdf



約 = approx.

*1 As the method of calculation for the amount of contaminated water generated was revised on March 1, 2018, it differs from the value published at the 20th Contaminated Water Treatment Countermeasure Committee (held on August 25,2017). Details of the revision are carried in the secretariat meeting materials of the 50th and 51st meeting of the decommissioning and contaminated water countermeasures team.
*2 The daily average per month is calculated from the daily average from the Thursday of the previous week to the Wednesday of the current week calculated based on data from measurements made at 7 a.m. each Thursday.

Figure 4. Amounts of Contaminated Water Generated and Changes in Inflow Amounts of Groundwater, Rainwater, etc. into Buildings

https://www.meti.go.jp/earthquake/nuclear/decommissioning/committee/osensuitaisakuteam/2023/06/06/2-1.pdf

Sample analysis of the groundwater bypasses showed a weighted average of 55 Bq/L of tritium in May 2023, with other nuclides below the detection limit. At the same time, according to a groundwater sample survey on the east side of the Units 1 to 4 turbine buildings, the May average of Groundwater Observation Hole No. 1-6, which has relatively high figures, is 1,422 Bq/L for tritium, 443,333 Bq/L for cesium-137, and 1,588,889 Bq/L for total beta. It can be inferred that the concentration is high because it was somehow mixed with contaminated water.

As shown in Fig. 2, in the area downstream from the sea side of the land-side water barrier, pumped up groundwater from well points and groundwater drains, the sea-side water barrier (steel sheet piles driven into the impermeable layer) prevent the outflow of groundwater to the dedicated port. That limits the leakage of this highly radioactive groundwater into the ocean to a certain degree. But, as we will see later, it does not stop all of it.

In addition to groundwater, there are multiple drainage channels on the site. Some of these formerly drained to locations outside the dedicated port, but were gradually replaced after the accident, and many now drain into the dedicated port. In February 2015, it was discovered that highly contaminated water was sometimes released into the open sea from the K drain, which drains rainwater from around the Units 1 to 4 buildings. Although TEPCO was aware of the problem as of April 2014, it did not reveal the measurement results for nearly 10 months (replacement work was carried out in 2016).

As shown in Fig. 5, the dedicated port is connected to the open sea at the opening at the tips of the seawalls. Seawater containing radioactive materials in the dedicated port mixes with seawater from the open sea and is released into the open sea as the tide rises and falls. If the leakage of contaminated water into the dedicated port is completely prevented, the concentration of radioactive materials in the dedicated port should decrease over time. However, checks of the concentration of radioactive materials in the FDNPS dedicated port (Figure 6) found that the concentration remained roughly constant even after the closure of the sea-side water barrier in September 2015. Thus, there are still pathways through which contaminated water is leaking.

This leaked radioactive material will eventually leak into the open sea, but TEPCO has not estimated the amount of radioactive material in the leakage. Radioactive material sampling in the dedicated port was therefore used to estimate the amount of the leak.

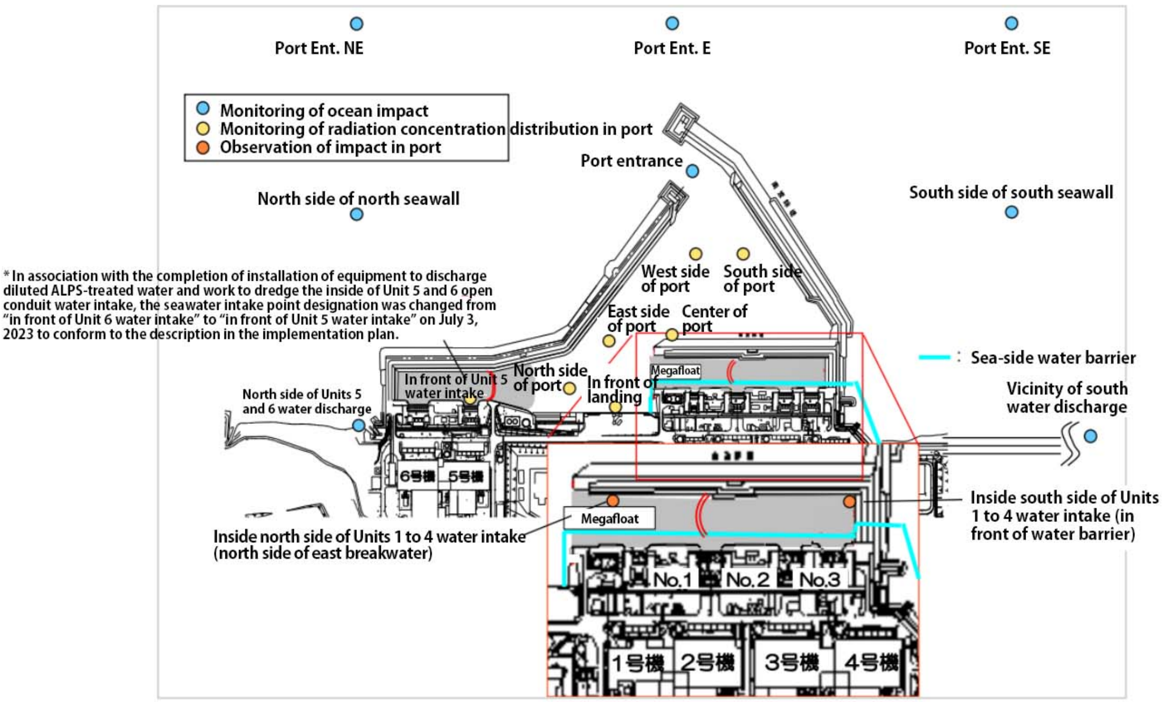


Figure 5. Port Structure and Seawater Sampling Locations at FDNPS

https://www.meti.go.jp/earthquake/nuclear/decommissioning/committee/osensuitaisakuteam/2023/06/06/3-6-2.pdf

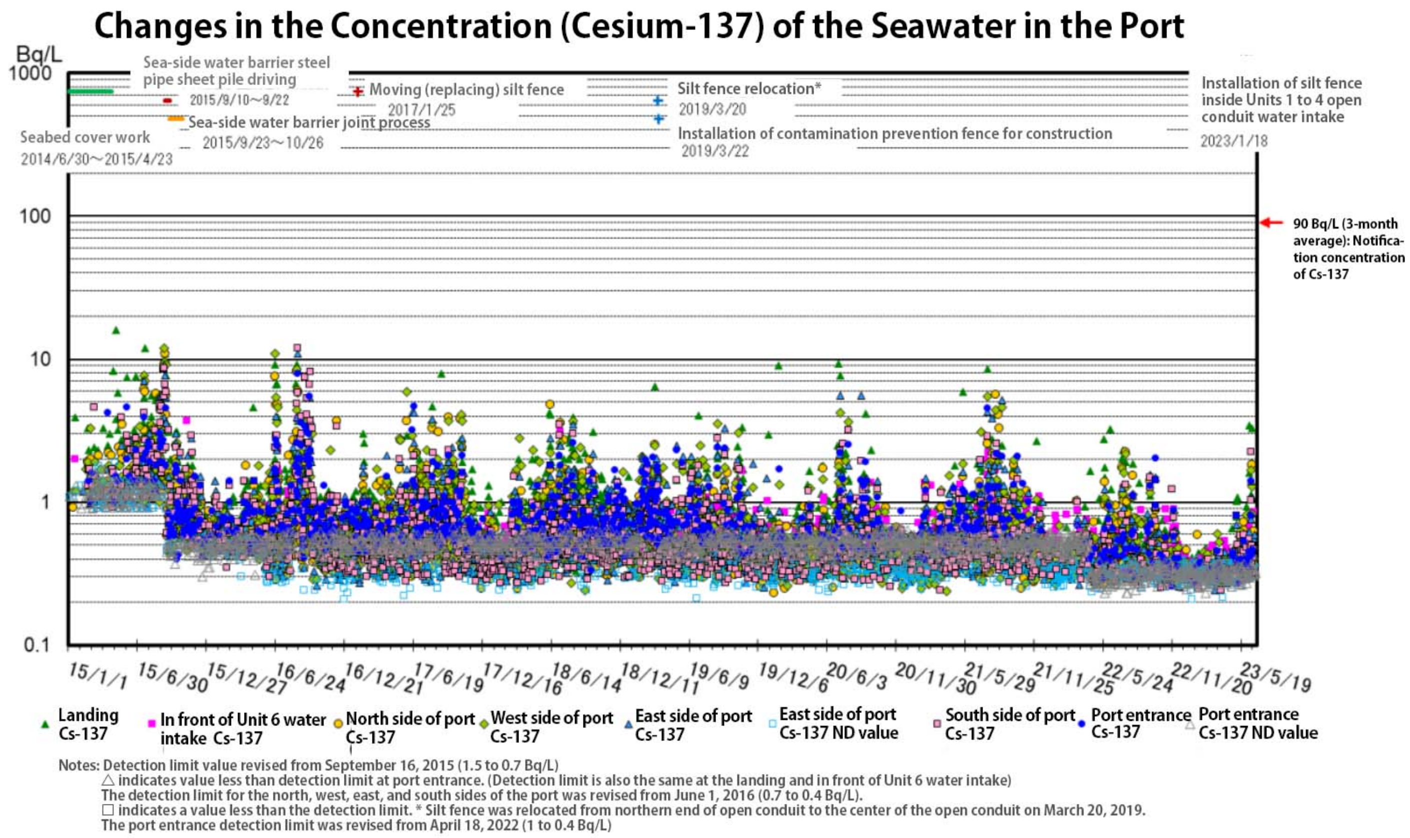


Figure 6. Changes in the Concentration (Cesium-137) of the Seawater in the Port at FDNPS

https://www.meti.go.jp/earthquake/nuclear/decommissioning/committee/osensuitaisakuteam/2023/06/06/3-6-2.pdf

ESTIMATION METHOD

To estimate leakage amounts, it is first necessary to estimate the total amount of radioactive material contained in the seawater. The total amount can be estimated by multiplying the radioactive content per liter, known from sampling surveys, by the amount of seawater in the dedicated port.

TEPCO is conducting sampling surveys at several points in the dedicated port. Of these, data from the west side of the port were used for the estimation. The reason for this is because it is thought that contaminated water flowing into the port would basically pass through this point. Since some data indicate that the amount of radioactive materials in seawater was "not detected (ND)" or "—," we calculated a higher estimate using only detected data and, in the case of ND, a lower estimate using detection limits. As a result, the radioactive material content of seawater in the dedicated port in May 2023 was estimated to be total beta: 14.25 Bq/L, cesium-137: 0.48 Bq/L, and tritium: 2.63 Bq/L for the high estimate, and total beta: 13.37 Bq/L, cesium-137: 0.38 Bq/L, and tritium: 2.32 Bq/L for the low estimate. Data from the south side of the port showed similar levels of radioactive material.

The area of the dedicated port, measured using Google Earth Pro, was about 254,000 m2. As, TEPCO has reported that for the depth of water inside the dedicated port, "The harbor is dredged to -6 m and a 170 m berth length landing area has been set up to allow vessels of about 3,000 tons to berth.”*2

[2] https://www.jstage.jst.go.jp/article/jaesj1959/11/5/11_5_306/_pdf

The depth of the dedicated port was thus set at 6.0 m in the deep case. Further, to prevent the dispersion of radioactive materials, work was carried out to cover the seabed of the dedicated port *3. The full draft of a 3,000-ton freighter is 5.5 m *4, and from a report *5, the cover thickness is assumed to be 50 cm. It was therefore assumed that the depth is 5.5 m in the shallow case.

Next, we estimate the extent to which seawater is exchanged between the open sea and the dedicated port. According to an existing study *6, the rate of exchange of seawater in private ports with open water is 0.44 per day, and thus this value is used. Seawater entering from the open ocean also contains radioactive materials, but according to the Ocean Monitoring Survey *7 conducted by Fukushima Prefecture, the cesium content of seawater collected from the vicinity of the intake was 0.010 Bq/L in February 2023, 0.07 Bq/L in March, and 0.003 Bq/L and 0.002 Bq/L at a point 2 km offshore, and these values were therefore not taken into account in the calculation.

Based on the above conditions, the amount of radioactive material leaking into the dedicated port was estimated using the following formula.

Amount of radioactive material leaking into the dedicated port (monthly) = Amount of radioactive material in seawater (Bq/L) × (Dedicated Port Area) × (Water Depth) × (Exchange rate with open ocean) × 1000 (ton/liter conversion) × (conversion to months)

As a result, the monthly release of radioactive materials in May 2023 was 290 billion Bq of total beta, 9.6 billion Bq of cesium-137 and 53 billion Bq of tritium in the high estimate, and 250 billion Bq of total beta, 7 billion Bq of cesium-137, and 43 billion Bq of tritium in the low estimate.

According to existing research *8, the monthly amount of radioactive material leaked to the dedicated port is estimated at less than 10 billion Bq at maximum as of March 2020 in the case of cesium-137. Since this estimate calculates the high estimate to be 9.6 billion Bq at the same point in time, these values can be assessed as being roughly comparable.

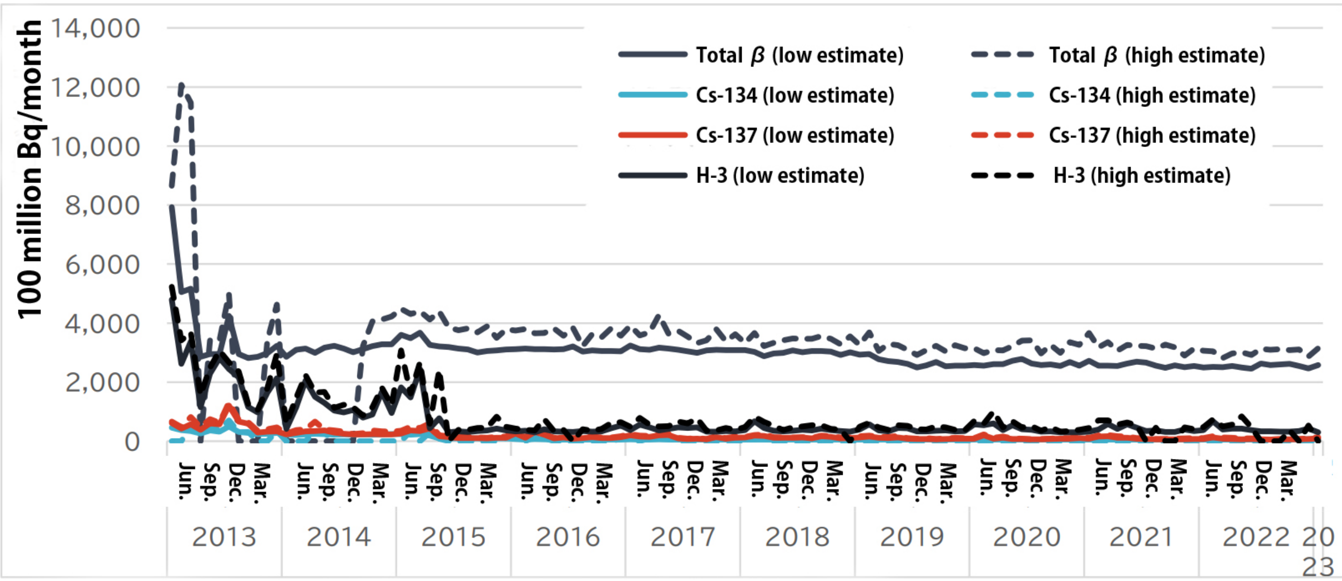


Figure 7. Estimate of Leakage of Radioactive Materials to the Dedicated Port Based on Monitoring Surveys at the Western Side of the Port (Bq/month)

[3] https://jcmanet.or.jp/bunken/kikanshi/2017/05/064.pdf
[4] https://www.mlit.go.jp/common/000206874.pdf
[5] https://www.jstage.jst.go.jp/article/jscejoe/73/2/73_I_288/_pdf
[6] https://bg.copernicus.org/articles/10/6107/2013/
[7] https://www.pref.fukushima.lg.jp/site/portal/moni-k.html
[8] https://www.jstage.jst.go.jp/article/taesj/21/1/21_J20.036/_article/-char/ja

SUMMARY AND DISCUSSION

While the issue of discharging ALPS-treated contaminated water into the ocean focuses solely on the radioactive materials contained in the water, FDNPS is also leaking radioactive materials through several other routes. The estimated monthly amount of radioactive materials currently being released from FDNPS confirmed thus far is summarized in Table 1.

The releases associated with ALPS-treated contaminated water significantly higher for tritium, but if we focus on cesium-137 and total beta, we can see that the amount of radioactive material currently leaking through various routes is far higher than that associated with the release of ALPS-treated contaminated water into the ocean. Looking at cesium-137, for example, the current leakage is about 1,750 to 2,400 times that contained in ALPS-treated contaminated water. Further, excluded from consideration was radioactive material that may be leaking directly into the ocean rather than by way of the dedicated port.

Table 1. Estimated Amounts of Radioactive Materials being Released from FDNPS (per month)

	Time of Estimate	Release to	Cs-137	Tritium	Total β
Additional Releases from Buildings	May 2023	Atmosphere	7.2 million Bq or less		
Releases due to Groundwater Bypasses	June 2023	Outside Dedicated Port		340 million Bq	
Releases due to Subdrains, etc.	June 2023	Dedicated Port		15.34 billion Bq	
Estimate of Releases to Dedicated Port	May 2023	Dedicated Port	7,000,000 Bq – 9,600,000 Bq	43 billion Bq – 53 billion Bq	
Reference: ALPS Treated Contaminated Water Release Target	Radiation Impact Assessment Report *9	Outside Dedicated Port	4 million Bq	1.833 trillion Bq	2.8 billion Bq *10

Comparing the release of radioactive materials associated with the oceanic release of ALPS-treated contaminated water with the release of radioactive materials from operational nuclear power plants is wrong in two senses. First, FDNPS has pathways through which radioactive materials are being released besides ALPS-treated contaminated water, and the amount of that radioactive material outflow is very large. Second, the radioactive materials released during normal operation of nuclear power plants are tritium, noble gases, radioactive iodine, etc., and not the diverse radioactive materials that are being released from FDNPS.

Comparing only releases of tritium contained in ALPS-treated contaminated water misrepresents the extremely serious status of FDNPS. According to monitoring posts set up at the FDNPS site boundary, radiation levels at the site boundary remain high at 0.3 to 1 microSv per hour (2.6 to 8.7 mSv per year) *11.

*9 https://www.tepco.co.jp/press/release/2021/pdf4/211117j0102.pdf p.55 modified from Fig. 5-4 Source term of ALPS-treated contaminated water (annual emissions) calculated by month

*10 Tritium and carbon-14 are included in the source term of the Radiation Effects Assessment Report. Although they emit β-rays, they were excluded from the total β because they cannot be detected by the GM counting tube used for the measurement of the total β radioactivity. The amount of carbon-14 emitted on the source term is approximately 9.2 billion Bq/month.

*11 https://www.tepco.co.jp/decommission/data/monitoring/monitoring_post/index-j.html

12 years after the accident, FDNPS is still releasing this incredibly large amount of radioactive material. Both TEPCO and the government are undoubtedly aware of this reality. Despite this, they are now attempting to release even the radioactive materials they have been able to manage in tanks to the outside world. The attitude of the government and TEPCO is extremely problematic.

The reason given for the release of ALPS-treated contaminated water is that by reducing the number of storage tanks for contaminated water, the site could be used for radioactive waste storage facilities when debris removal or the demolition of buildings are carried out in the future. But for an estimated 880 tons of debris, the removal plans we see at the moment are in terms of grams, and that itself is severely hampered by extremely high radiation levels. 12 years after the accident, it has become clear that the goal of completing decommissioning in 30 to 40 years, assumed at the time of the accident, is completely unrealistic. Setting out to remove debris prematurely is likely to be a task that will expose workers to excessively high levels of radiation, very possibly with little to gain. The methodology itself should be reviewed with an eye toward decommissioning over hundreds of years. The need to release ALPS-treated contaminated water would then naturally have to be reviewed.

Even if the current decommissioning plan is to continue, has everything possible been done to reduce external emissions to the absolute minimum? For example, storage facilities will be needed to manage removed debris and demolished buildings. Concrete would naturally be used for such facilities, but could the contaminated water not be used to make the concrete for such facilities, since people would not need to approach them very often?

FDNPS has already released extremely large amounts of radioactive materials during the accident and thereafter. Reducing further releases as much as possible is the responsibility of TEPCO, which caused the accident, and of the government, which has pursued a nuclear policy.

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