ALPS-Treated Water Stored at the TEPCO Fukushima Daiichi Nuclear Power Station

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Introduction

Measures are currently being taken at the Tokyo Electric Power Company's (TEPCO) Fukushima Daiichi Nuclear Power Station to deal with "contaminated water", which contains high concentrations of radioactive substances generated as a result of the nuclear power station accident there in 2011. The issues involved come with a wide variety of technical terms that are not familiar to many people. Both the government of Japan and TEPCO are also aware that they have not made sufficient efforts to provide detailed and easy-to-understand information on the state of affairs regarding the contaminated water after it is processed. This is an attempt to fill this gap by providing basic information on the contaminated water management issue, as well as the latest news on the state of discussions on the measures to be taken.

What Is Contaminated Water?

The accident at Fukushima Daiichi following the Great East Japan Earthquake and subsequent tsunami caused the meltdown of nuclear fuel. The re-solidified fuel remains in the nuclear reactors as "fuel debris" and is kept cool by continuous water injections. However, as the water comes into contact with the fuel debris, "contaminated water" containing high concentrations of cesium, strontium, and other radioactive substances is generated and it remains in the reactor buildings. In order to prevent this contaminated water from leaking out to the external environment, controls are in place to maintain the groundwater level above the level of contaminated water in the buildings. As a result, the groundwater flows into the reactor buildings, which were damaged by hydrogen explosions and other causes, and rainwater also flows in through the roofs of the damaged buildings. This groundwater and rainwater mixes with the highly-concentrated contaminated water, generating yet more contaminated water. This means that the contaminated water is increasing day by day.

Photo: TEPCO

Tanks for ALPS-treated water at Fukushima Daiichi Nuclear Power Station

Basic Principles of Measures for Contaminated Water

In September 2013, in the face of the continuously growing amounts of contaminated water, "The Three Principles Concerning Management of Contaminated Water" were established by the Nuclear Emergency Response Headquarters. This meant that the government takes the lead in taking necessary measures. Under these principles, the government has undertaken preventive and multilayered measures aimed at an early resolution of the contaminated water issue.

Measures for contaminated water have been taken under the basic principles of i) Preventing leakage, ii) Isolating it, and iii) Removing it.

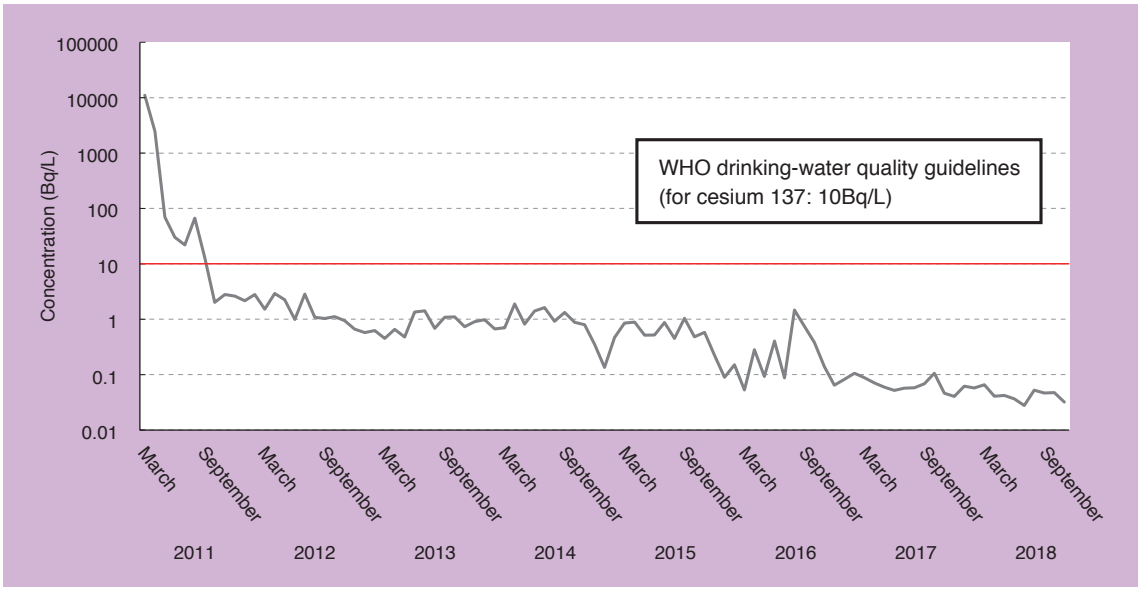
i) Measures to prevent leakage of contaminated water

Of foremost importance is to keep contaminated water from leaking out to the open seas. For this purpose, a watertight, sea-side impermeable wall, which is 780 meters long made from stainless steel, was installed in October 2015, a major move forward in measures against contaminated water.

The risk of groundwater containing radioactive substances flowing out into the open seas is reduced by holding back the groundwater with this sea-side impermeable wall as well as by drawing the groundwater through wells installed in the seawall area. As a result of these efforts, the concentration of radioactive substances beyond the harbor that serviced Fukushima Daiichi is being maintained at a low level. The substances are well within the World Health Organization's (WHO) guidelines for drinking-water quality (GDWQ),

CHART 1

Concentration of radioactive substances in the surrounding area



Source: TEPCO

the International Atomic Energy Agency (IAEA) has commented that public safety has been secured, and the maritime environment is stable. In the harbor itself, it has been confirmed that the concentration of radioactive substances is improving, and the government will continue managing the situation properly *(Chart 1)*.

ii) Measures to isolate groundwater from contamination sources

We have already touched on the generation process of contaminated water. If the amount of groundwater flowing into the buildings can be suppressed, this will lead to reducing the amount of contaminated water that is generated. Keeping groundwater away from the buildings and limiting the amount of groundwater flowing into the buildings mean stabilizing the underground water level and keeping it low, and at the same time keeping it higher than that of the contaminated water in the reactor buildings.

One example of "Isolate" is pumping up the groundwater through wells ("subdrains") which are installed near the buildings. By pumping up groundwater through the subdrains, the groundwater level around the buildings is lowered, with the result that groundwater inflows into the buildings are suppressed and at the same time groundwater outflows on the sea-side area of the buildings are contained.

In addition, a "frozen-soil wall" encircling the buildings has been constructed, reducing the amount of groundwater flowing into the buildings. The frozen-soil wall is created by freezing the surrounding grounds by sending refrigerants through "freezing pipes" installed in the ground. It is estimated that the frozen-soil wall has the effect of reducing the amount of contaminated water generated daily by half.

Other measures are also being taken, such as drawing off the groundwater in the mountain-side before it nears the buildings and paving the premises to reduce the amount of rainwater permeating the soil and generating new groundwater.

Through these and other measures, a system for stably controlling the groundwater level and not allowing groundwater to flow into the building has been installed. As a result, the amount of contaminated water generated daily has been reduced from approximately 490 m^3 in FY2015 to 180 m^3 (FY 2018 average).

Since no contaminated water is allowed to leak out of the buildings, the unavoidable inflow of groundwater creates new contaminated water. But measures will continue to be taken, such as a measure against rainwater which is a cause of increasing groundwater, to further reduce risks with the aim of reducing the daily generation of contaminated water to 150 m^3 by 2020.

iii) Measures to remove contamination sources

The contaminated water that is generated is treated by a series of purification facilities to reduce the risks from it. The purification treatment of the highly-concentrated contaminated water that had been generated since just after the accident and stored in tanks was

concluded for the time being in May 2015. This considerably reduced the potential risk from a leakage of the contaminated water.

Currently, "ALPS-treated water", water treated by the Advanced Liquid Processing System (ALPS) and other purification facilities, is safely stored in tanks on the premises. But this still contains tritium, a radioactive substance. To determine how to handle this ALPS-treated water, comprehensive discussions are underway in a government subcommittee from both a technical perspective and social perspective.

What Is ALPS-Treated Water?

The water that is generated when contaminated water is given purification treatment is called ALPS-treated water. Let's take a closer look at this.

Of the multiple facilities used to purify the contaminated water, the core of the process is a removal facility called the ALPS. This system has the capacity to satisfactorily remove 62 different radioactive substances.

Until 2013, two years after the Great East Japan Earthquake, the ALPS was still under development. Being unable to sufficiently purify the highly-concentrated contaminated water, the liquid had to be stored in tanks on the premises.

After the ALPS went into operation in 2013, it became possible to extract a wide variety of radioactive substances from highly-concentrated contaminated water. This ALPS-treated water is stored continuously in tanks on the premises. Precautions are taken to prevent leaks when storing the ALPS-treated water on the premises, such as surrounding it with double weirs and conducting regular patrols.

Although the ALPS-treated water still contains tritium, which even the ALPS cannot remove, most of the radioactive substances have been removed. It is very different from contaminated water in terms of safety.

Is ALPS-Treated Water Processed & Managed Properly?

In a nuclear power station, the radiation dosage at the "boundary of the premises" of the power station is one of the standards for safety management. The Nuclear Regulation Authority stipulates that the additional radiation dosage at the boundary of the nuclear power station premises must be limited to "under one millisievert (mSv) per year".

Highly-concentrated contaminated water emits a high level of radiation even when it is contained in tanks, affecting the environment. When highly-concentrated contaminated water was being stored on the nuclear power station premises, the radiation dosage at the boundary of the premises reached 10 mSv per year, well above the one mSv per year standard.

After the ALPS went into operation, thanks to the ALPS purification ability, the radioactive substances were removed and the additional radiation dosage was achieved at the one mSv standard in March 2016. This meant that the regulation standards for "storing" treated water in tanks were now met.

Some people are saying that ALPS-treated water stored on the premises of Fukushima Daiichi "is not being treated sufficiently". What does this mean?

Actually, there are two "regulatory standards" for contaminated water: i) the standard for storing it in tanks and ii) the standard for releasing it into the external environment. The ALPS-treated water currently stored at Fukushima Daiichi satisfies standard i) for storage. Standard ii) is obviously stricter than the standard i). What is meant when people say that the ALPS-treated water "is not being treated sufficiently" is that standard ii) is not being met.

Ideally, i) and ii) would be satisfied simultaneously. However, it will take time to meet standard ii). So, it was decided to start operating the ALPS in order to prioritize meeting standard i) for storage so that the water could be stored safely in tanks on the power station premises. This means that there is ALPS-treated water currently stored in tanks that does not meet standard ii) for release.

How much of the treated water satisfies standard i) or ii)? "A" in *Chart 2* represents the treated water in the tanks that satisfies standard ii) other than the irremovable tritium, while the remainder represents the treated water that satisfies standard i) but not standard ii).

However, this ALPS-treated water is not released into the external environment as it is. Going forward, standard ii) must be met when the ALPS-treated water is to be released into the environment.

TEPCO has expressed its intention to satisfy standard ii) other than the irremovable tritium by putting the ALPS-treated water through the purification process once again before it is to be disposed of.

Conclusion

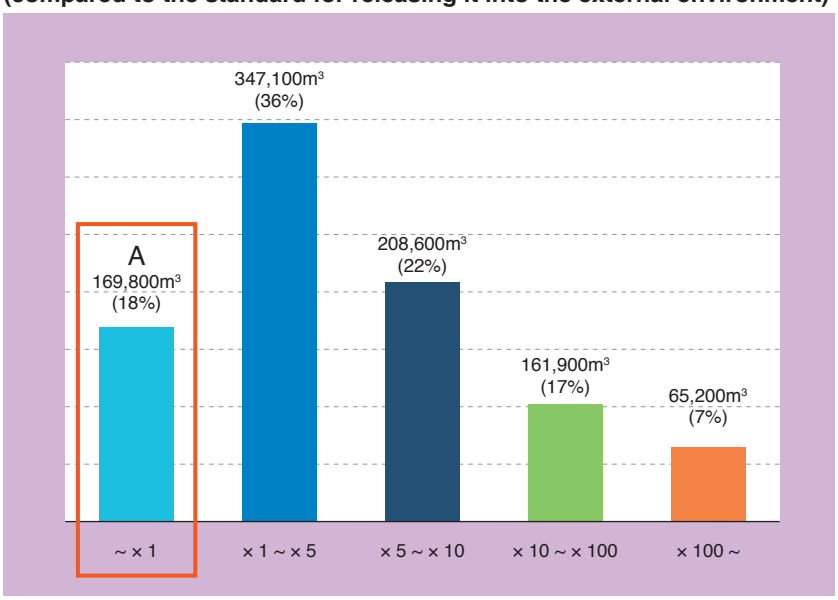
In any case, no decision has been made on how the ALPS-treated water stored in tanks is to be handled, and the discussions are still ongoing. The government of Japan will listen carefully to the local populace as well as experts, conduct broad-based discussions, and undertake measures with safety and security as the top priority.

Moreover, there is further progress in the decommissioning work and when the retrieval of the debris is completed, there will be no more generation of contaminated water, and the risk from contaminated water will be greatly reduced.

The government will continue to go forward steadily in managing

CHART 2

Current state of ALPS-treated water in storage
(compared to the standard for releasing it into the external environment)



Source: TEPCO

and controlling the contaminated water while monitoring the harbor area and groundwater, among other things, in order to dispel public concern both here in Japan and abroad.

Note: What is this tritium that cannot be removed by ALPS?

The ALPS-treated water includes tritium, which cannot be removed even by treatment equipment.

Tritium is a radioactive hydrogen isotope and has chemical properties almost identical to those of ordinary hydrogen.

Tritium is generated naturally as the radiation from outer space that constantly rains down on the Earth, called "cosmic rays", interacts with the Earth's atmosphere. The tritium connects with oxygen to exist as "tritiated water" in rivers, the seas, and other bodies of water. Tritium is also contained in rainwater, tap water, and the vapor in the atmosphere, and is used to date groundwater. It also exists in the human body, as it is ingested through tap water, for instance.

In nature, approximately seven × 10^{16} Becquerels of tritium are generated per year. It is estimated that approximately 100 to 130 × 10^{16} Becquerels of tritium exist naturally at any time.

Tritium may also be generated artificially. There is the tritium that was released by the nuclear tests conducted from 1945 to 1963. Tritium is also generated by nuclear fission at nuclear facilities (nuclear power plants and reprocessing facilities) in Japan and abroad. The tritium generated by nuclear facilities is released into the oceans and the atmosphere by the respective nations according to their respective domestic regulations.

The radiation emitted by tritium is in the form of β-rays. The β-rays from tritium are very low in energy and can be stopped by a single sheet of paper. Even if someone is exposed to β-rays from tritium outside of the body, they are stopped by the skin. Thus, it is "internal exposure", the effect of a radioactive substance after it enters the human body, that is the subject of consideration regarding the impact on health.

Since tritium exists naturally as "tritiated water", we ingest tritium that exists in the air around us in gaseous form as water vapor or tritium in liquid form (tritiated water) that is included in tap water.

However, since the radiation generated by tritium is weak, the radiation dosage from, say, 10,000 Becquerels is merely 0.00019 mSv*. According to up-to-date research, even if tritiated water is ingested, it is discharged externally just like ordinary water, and is not accumulated in any specific organ or concentrated within living organisms.

* The exposure from one chest-ray examination is 0.06 mSv. JS