Task Force for Tritiated Water – "Summary of previous discussions"

1. Introduction

○On December 10th, 2013, the Committee on Countermeasures for Contaminated Water Treatment established "Preventative and Multilayered Measures for Contaminated Water Treatment at the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company - Through completeness of comprehensive risk management -".

○In the document, the committee made it clear that even though treatments such as "removal of contamination sources," "isolation of water from contamination sources," and "prevention of leakage" are conducted, the risk arising from the water treated through the multi-nuclide removal equipment (hereinafter called "tritiated water") would eventually remain.

○Accordingly, it was decided to set up a task force under the committee, to evaluate various options comprehensively. The task force started their discussions on December 25th, 2013.

○With regard to treatment of tritiated water, an IAEA expert team also advised to "consider all options."

○On December 20th, 2013, the Nuclear Emergency Response Headquarters established "Additional Measures for Decommissioning and Contaminated Water Issues at TEPCO's Fukushima Daiichi NPS." In the document, it is stated that "(We) make a comprehensive evaluation of all options for tritiated water containing residual risks as soon as possible and consider appropriate measures."

2. Purposes and conditions of the task force

○Purposes of the task force are to select various options such as separation, storage, release, etc. as basic information which can contribute specifically to the decision on handling of the tritiated water, which is one of the issues on contaminated water in the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company, and to clarify items to be evaluated such as risks, environmental impacts, cost-benefit, etc. for each selected option, so that a comprehensive evaluation can be done. (Excerpt from the charter of the task force)

○Meanwhile, the task force is to professionally consider tritium and to comprehensively evaluate various options, so its task includes neither coordination of opinions of concerned parties, nor selection of a definitive option.

○It is supposed that nuclides other than tritium would be able to be separately removed through the multi-nuclide removal equipment, and that tritiated water would be treated as soon as possible within the time period until decommissioning.

3. Clarification of basic information

（１） Physical properties of tritium

○Tritium, one of the isotopes of hydrogen, contains a proton, an electron and two neutrons. It also exists in nature; natural water contains tritium on the order of 1 Bq/L, and a human body contains a few tens of Bq per person.

○The half-life of tritium is 12.3 years.

After tritium is ingested, one half of the amount will be excreted in ten days (in the case of water), or in forty days (in case of an organic substance) through metabolism (biological half-life).

○The energy of β-ray emitted from tritium is so low (18.6 keV at most) that it can be shielded with a sheet of paper.

（２） Status of tritium in the Fukushima Daiichi Nuclear Power Station

○The total volume of stored contaminated water is approx. 460,000 m^3, containing approx. 73,000 m^3 treated through the multi-nuclide removal equipment (as of April 22nd, 2014).

The treatment of the water stored in the tanks through the multi-nuclide removal equipment will have been completed by March, 2015. The total capacity of the tanks will have been increased by 800,000 m^3 by the end of FY2014.

○Tritium concentration of the water stored in the tanks is being gradually reduced by dilution with groundwater inflow, hence it varies according to the stored period. The range is 0.5 - 4.2 million Bq/L (from September 2011 to October 2013). The accumulated volume of tritium included in the water stored in the tanks is approx. 2.3 g (approx. 8.3×10^{14} Bq, as of March 25th, 2014).

(※) This value corresponds with a calculation with the assumption that tritium exists in the form of a tritium atom.

（３） Environmental dynamics of tritium and its influences

○Tritium is a nuclide which emits a low energy β-ray, accordingly, concerning influences on human body, only internal exposure by inhalation and injection must be considered.

○Tritium in an organic substance has two forms, i.e. FWT (Free Water Tritium) and OBT (Organically Bound Tritium). OBT is easier to be absorbed in the organism than FWT, and its biological half-life is longer than FWT, so it is important in dose evaluation.

○In the aquatic environment, FWT concentration in the organism and tritium concentration in water rapidly reach equilibrium, and biological concentration from water to organism does not happen, therefore OBT concentration in an aquatic organism does not exceed tritium concentration in water.

○The figures for tritium existing in the contaminated water of the Fukushima Daiichi Nuclear Power Station (as of December 24th, 2013) are one hundred-thousandth of the tritium in the environment (2010), and one hundredth of the yearly production of tritium by cosmic rays, etc.

○A radiation dose of marine life is evaluated through evaluation of “standard lives” with various shapes, such as flatfish, trout and crab. Generally, it is calculated through radioactive concentration (Bq/kg-life) (※) using the conversion coefficient.

(※)This unit represents concentration measured under a condition where an environmental sample is not desiccated.

○For example, supposing that tritium is distributed equally in the body of demersal fish, that the tritium concentration in the seawater is the same as the density limit of 60,000 Bq/L, and that the concentration coefficient is 1, then the exposure dose rate amounts to 0.0048 mGy/day. (For reference: “In the aquatic environment it would appear that limiting chronic dose rates to 10 mGy/d^{-1} or less to the maximally exposed individuals in a population would provide adequate protection for the population." (an evaluation standard of IAEA))

○There are two types of radiation effects to the human body, i.e. probabilistic effect (mutation) and deterministic effect (apoptosis or cytopathy). If the radiation dose is low, a probabilistic effect will become closer to an naturally occurring effect.

○A radiation dose through internal exposure is evaluated as the dose exposed for fifty years (for an adult) or until the age of seventy years old (for an infant) after intake of radioactive substances (committed dose).

○In the 1960s in Europe, there occurred radiation accidents involving researchers or workers at factories using luminous paint containing tritium, and two fatal cases were reported.

○In blood, 97 percent of inhaled HTO becomes HTO, and 3 percent becomes OBT. The HTO decreases by half in ten days, and the OBT in forty days, through urination and defecation.

○Influences of radiation depend on the dose rate (Even though exposure doses are even, if the radiation exposure per hour (dose rate) is small, the influences of radiation are also small.)

（４） Dispersal of tritium in the environment

○The behaviors of tritium released in the atmosphere are the following: turbulent diffusion in the atmosphere, dry or wet deposition into the ground, advection or diffusion inside of the ground, evaporation from the ground surface, etc.

○With regard to diffusion in the ocean, ocean fluctuations are reproduced using the ocean general circulation model with data of meteorological and hydrographic conditions, data of heights of the ocean surface, etc., then concentration in the sea is calculated using the ocean diffusion model, which combines information on the release of tritium with the ocean fluctuations.

The concentration varies in accordance with the manner or location of the release; however, generally the more distant from the release point, the less concentration becomes. (According to a provisional calculation, if the measurement is done 10 km downstream, the concentration decreases by a factor of ten, and 100 km downstream by a factor of one thousand.)

○Processes on the land surface, on the sea surface, processes of the secondary release, etc. are reproduced with a combination of atmosphere, continent and ocean models.

4. Clarification of knowledge required for consideration of options and items to be evaluated

(1) Technology for tritium separation

○Evaporation method (water evaporation, hydrogen evaporation), isotope exchange method, electrolysis method and other methods have been developed, but each method has some drawbacks and advantages.

○Separation of tritium has been conducted in plants in overseas countries such as Canada and Korea, and Fugen in Japan. However, compared to previous experiences, the concentration of the tritiated water in the Fukushima Daiichi Nuclear Power Station is smaller by a few factors of ten, and the quantity larger by a few factors of ten.

○Regarding separation, treatment capacity of plants, removal target, treatment of concentrated or depleted tritium, period, costs, etc. have to be considered.

(2) Geological disposal of radioactive waste

○There are some disposal methods of radioactive waste, such as shallow land disposal (trench disposal, pit disposal) for low-level radioactive waste, "geological disposal" for high-level radioactive waste, etc.

○There are some examples of trench disposal of very low-level radioactive waste without engineered barriers such as concrete pits, etc., and concrete pit disposal, where low-level radioactive waste is disposed of in the form of solidified waste packages.

○In a safety assessment for shallow land disposal, during the monitoring period (approx. 50 years), the dose of the public is assessed at the spot where it reaches the highest value on the boundary of the site, to verify it is less than the numerical guide for dose (reference dose: 1 mSv/y, numerical guide for dose: 50 μSv/y). After the monitoring period expires, it is verified whether or not the dose is less than the reference dose (reference scenario: 10 μSv/y, altered scenario: 300 μSv/y).

○Regarding leakage or migration from a trench disposal facility or a pit disposal facility, the assessment is conducted through modeling of advection and diffusion in the soil. (This is a conservative method of assessment, since it does not take into account the effect of the drums, etc., even though waste is disposed of after being put in them.)

（3）Items to be evaluated or points of attention from societal point of view

○When choosing options for each issue, it is important that the choice be done fully considering eyes of the people, especially of the local residents.

○The local residents or the people are less familiar with tritium than cesium and have less information, hence they see the issue of tritium as a new one.

○There are opinions such as “The issue of tritium has emerged after passing more than two years from the accident, this fact could increase a sense of distrust. Do not take a heavy toll on the Fukushima people anymore.” These opinions must be taken into account.

（4）Regulatory criteria for tritium

○In food sanitation regulations, there are no specific references to tritium, because at the time when the standards were established, the situation was one where “It is unthinkable that the radiation dose of tritium could reach a significant level in foods.”

○In "Items required for measures to Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Co., Inc. on designation as Specialized Nuclear Facility" (Decision of the Nuclear Regulation Authority, November 7th, 2012), it was required that the effective dose (evaluated value) of rubble, contaminated water, etc. produced after the emergency and stored in the facilities must be less than 1 mSv/year on the boundary of the site.

○However, along with transportation of contaminated water from underground reservoirs to the tanks and increase of stored contaminated water, etc., the effective dose on the boundary of the site amounts to approx. 8 mSv/year (Application for permission of changes of the implementation plan, December 2013). Accordingly, the Nuclear

Regulation Authority adopted "On the regulatory requirements for fulfillment of the limitation of the effective dose on the boundary of the Fukushima Daiichi Nuclear Power Station site (The Nuclear Regulation Authority, February 26th, 2014)," ordering TEPCO to clearly define the period of fulfillment of the limitation of the effective dose, etc. (At the end of March 2015, less than 2 mSv/year, at the end of March 2016, less than 1 mSv/year).

○On evaluation of the above-mentioned effective dose on the boundary, if it is possible to be exposed to external radiation, and to inhale or orally intake radioactive substances in air or water, it is required that the sum of the "proportion of the yearly effective dose through external exposure to 1 mSv", "proportion of radioactive substances in the air to the concentration limit," and "proportion of radioactive substances in water to the concentration limit" be one.

○Meanwhile, "Announcement of decision of necessary matters to security of reactor facilities and protection of specific nuclear fuel material in the Fukushima Daiichi Nuclear Power Station of Tokyo Electric Power Company (The Third Announcement of the Nuclear Regulation Authority, 2013)" stipulates concentration limits of radioactive substances in air and in water. However, these limits are adoptable only when the type of radioactive substances in air or in water is clear, and there is only one type.

(For example, if the radioactive nuclides is nothing but tritium, the concentration limits are 0.005 Bq/cm^3 in air and 60 Bq/cm^3 in water, respectively.)

（５） Overseas examples

○Example after an accident (United States, Three Mile Island accident)

・National Environment Policy Act (NEPA) stipulates assessment of federal actions which have environmental impacts. Environmental impacts are assessed through the following three steps: (i) Categorical Exclusion, (ii) Environmental Assessments, and (iii) Environmental Impact Statements. In Environmental Impact Statements, quality of air, water resources, biological resources, health and safety of humans, etc. are chosen as items to be assessed as impacts against environmental resources.

・15 alternatives were rejected out of 24 alternatives, and the regulatory authority (NRC) assessed that impacts of 9 alternatives were very small.

・The implementing entity chose alternatives out of 9 after explanation to stakeholders, etc.

・It took ten years to dispose of tritium after the choice of evaporation. (In the Three Mile Island, the volume of water and its increase were not large, so they could spend a long time.)

○Other examples

1） Examples in France (i) (Tritium white paper, etc.)

・An independent regulatory authority (ASN) is in charge of regulation, authorization, etc.

・The volume of released tritium at La Hague (the largest volume in France) is 12,000 TBq liquid and 70 TBq gas, respectively.

・In France, the total volume of released radioactive substances has had decreasing tendency in these two decades; however, the volume of released tritium, which cannot be treated, has not been decreasing.

・Although it was internationally recognized that the health impact of tritium is small, domestically more than a few people expressed their concern, hence ASN drew up the tritium white paper in 2010.

・In the process of drawing up the white paper, technologies to remove tritium were explored all over the world, but they concluded that there were no adoptable solutions with affordable costs, and this conclusion was shared with the stakeholders.

・After drawing up the white paper, operators periodically prepare reports to explain up-to-date solutions of tritium treatment, and the regulatory authority reviews them.

2） Examples in France (ii) (Case of IRSN)

・IRSN, a supporting organization of the regulatory authorities, conducts researches of tritium behaviors in the environment in order to enable more realistic dose evaluation of humans and biological bodies.

・There is uncertainty in the ecosystems in the ocean or on land, so IRSN plans to implement certain programs to validate them.

3） Examples in the UK (i) (Culham Centre for Fusion Energy)

・30 options were taken into consideration, and they were narrowed down to 10 options through preliminary assessments.

・The assessed items (there were 16 criteria altogether) were the following: applicability/feasibility, economic efficiency, environmental impacts, health and safety, regulatory and external relationships
・Internal teams conducted the assessments following advice from the regulatory authority.

4） Examples in the UK (ii) (Dialogue with stakeholders)
・Introduction of dialogues among stakeholders when tritium was released from the reprocessing plant in Sellafield to the ocean
・There was an explanation stating that they spent plenty of time for the dialogues of the stakeholders, that many people engaged in fishing, including people from other neighboring countries, participated in the dialogues, and that it was meaningful for the regulatory authorities to take part in the dialogues, etc.

5． Various options and items to be evaluated

（１） Options (See the attached figure)

○We have clarified logically possible options in consulting overseas examples. Considering the definitive solution, the following options are advantageous: "Injection and disposal into the geological formation," "Release to the sea," "Release to the Atmosphere in the form of steam," "Release to the atmosphere as hydrogen gas after reducing to hydrogen," and "Underground burial and disposal after solidification or gelification." We have not given up on the storage option, but it should be noted that this option is nothing but a temporary measure.

○Dilution and isotopic separation have been evaluated as pre-treatments for the definitive solution. Additionally, if isotopic separation is adopted, then both an option for depleted tritium and one for concentrated tritium are needed.

（２） Items to be evaluated

○The following items are suitable to be evaluated: impacts and risks to the environment, marine products and human bodies, treatment period, costs for the solution, technical feasibility (technical maturity, technical applicability, domestic and foreign experiences), controllability (certainty of implementing the option, including difficulties in legal regulations, possibility of damages caused by harmful rumors), and availability of measures to confirm safety.

6 . Items to be evaluated and issues in future

○Going forward, more detailed consideration is needed of the items to be evaluated for each option previously selected.

○Accordingly, the following issues must be considered in detail.

Examples)

・Technical Feasibility;

Demonstration tests for validating technical feasibility of separation techniques, etc., if needed.

・impacts and risks to the environment, marine products and human bodies, costs, work period

To define simple concepts (location, transportation, facilities, etc.) for each option, and to provisionally calculate impacts and risks, and costs or work period needed for the disposal itself such as installation of facilities.

・Others;

The way to communicate with stakeholders (including the method to announce and transmit evaluation results of each option and data regarding them. However, this task force does not cover the issue of stakeholders' acceptance.)

etc.