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How to manage tritium.

The Atomic Energy Society of Japan held tritium workshop in Tokyo

"Even though we can remove cesium and strontium from contaminated water produced in Fukushima Daiichi Nuclear Power Station, tritium still remains. Tritium is not concentrated in a living body. Therefore, the Accident Investigation Board of the Atomic Energy Society of Japan concluded that, among various methods applicable to tritium management, releasing the tritiated water into the ocean after diluting it is the most reasonable option from the perspective of risk reduction."

The tritium workshop organized by the Atomic Energy Society of Japan was held in Tokyo on 4th March, 2014. The comment above was given by Professor Satoshi Konishi from Kyoto University in the workshop as an answer to questions asked by the audience. Professor Konishi further continued, “There is an option to concentrate tritium and manage it on earth, but this method will cause another risk. Tritium is one of the naturally existing nuclides, so health damage will not be caused if the contaminated water is released into the sea under well-controlled conditions. The most serious problem would be the damage caused by harmful rumors or misinformation, and for this reason it is important to gain an understanding from local residents and society."

At TEPCO’s Fukushima Daiichi Nuclear Power Station, the contaminated water is still produced, so processes for removing strontium and cesium are being carried out using a cesium removal equipment (SURRY, KURION) and multi-nuclide removal system (ALPS). However, it is not easy to remove tritium completely, because the behavior of tritium is similar to that of water. For this reason, about 43 million tons of processed contaminated water is stored in about a thousand tanks at the site of the power plant as of the end of January 2014. Furthermore, since the amount of the contaminated water is increasing by approximately 400 tons every day, the management of the contaminated water is becoming the major problem to be solved.

Concerning the behavior of tritium, on the other hand, there are lots of scientific results that have been accumulated for a long time. Under the auspices of the Japan Atomic Energy Agency, the Atomic Energy Society of Japan held a workshop to share scientific and technological knowledge related to tritium, and the countermeasures for the problems related to tritium were discussed in the workshop.

Summary of the workshop is as follows.

Tritium in environment

Professor Noriyuki Momoshima, Kyushu University

Water is one of essential materials to maintain the life of animals and plants on earth. About 60-70 % of our body is composed of water, and water contains a certain amount of tritium. In the upper atmosphere, tritium is constantly produced by the nuclear reaction between nitrogen or oxygen that consists atmospheric gases and neutron or proton. Tritium exists in vapor in air, rain, sea water, and inland water, and is circulating with water in nature. The human race has been consuming tritium in the environment through food and drinking water from ancient times.

The artificial tritium had been released into the troposphere and stratosphere by the atmospheric nuclear tests, which were often conducted in 1950-60. Therefore tritium concentration in rainfall increased after 1952. The value of tritium concentration in rainfall became maximum in 1963-1964, and the value in this period was one-hundred times higher than that of the natural level. After that, tritium concentration in rainfall around the world gradually decreased year by year because the atmospheric nuclear test experiments were ended. Now the tritium concentration returned to the natural level. Although tritium derived from nuclear tests finally migrates to the sea, the increase in the tritium concentration in sea water is negligible because huge amount of water exists in the ocean.

Tritium is produced by ternary fission of uranium in the nuclear reactor fuel rods, and it is stored in the spent nuclear fuel. Tritium is not being collected in most of the nuclear power plants and nuclear fuel reprocessing plants, and all the tritium is released to the environment. Tritium released into the ocean is diluted with a large amount of sea water. Also, a portion of tritium released to the environment as a gaseous waste from the stacks falls in the vicinity of the plants directly or with rain, and is diluted with rainwater.

Tritium was released into the environment by the accident at the Fukushima nuclear power station. At that time, a little increase in the tritium concentration in inland waters was observed in Fukushima Prefecture near the nuclear power station. However, it can be said that there was little influence on the environment because the tritium levels were less than those in the 1980s.

Effect of tritium on environmental ecosystem

Ms Kiriko Miyamoto, Scientific Adviser of Marine Ecology Research Institute

The range of β-rays emitted from tritium is very short, and energy of the β-rays is fairly low. Therefore as to the radiation exposure to tritium, we usually consider only internal exposure. The internal exposure effects are divided into two categories. One is the effect of inhalation through lungs and skins, and the other is that of food and water intake.

The dose coefficient is defined as the level of the effective dose (Sv) when a person takes one Becquerel (Bq) of radionuclides. In the case of tritium, the dose coefficient is fairly small, and the value is only 1/1000 of those for Cs-137.

Since tritium is an isotope of hydrogen, it exists in vivo in the form of water or the form binding to other atoms such as carbon, oxygen, hydrogen, nitrogen, and sulfur. The tritium in the former form is called as tissue free water tritium (TFWT) and that in the latter form is called as organic bound tritium (OBT).

There have been many studies concerning how tritium migrates in the environmental ecosystem under equilibrium condition. The following is the summary of the results of these studies. The TFWT concentration becomes the equilibrium state which is equal to the tritium concentration in environment. On the other hand, the concentration of OBT becomes equal to the tritium concentration in environment or lower than that, which is called as "isotopic fractionation equilibrium state", and is never concentrated. In an environmental ecosystem under non-equilibrium condition, the tritium concentration will change in accordance with the dynamic model with taking in and out until it becomes an equilibrium state.

Isotope separation of tritium

Professor Satoshi Konishi, Kyoto University

Water on the earth contains deuterium and tritium, both of which act in the same way as hydrogen in the environment and human body.

As to the technology for isotope separation of a large amount of water, already established or expected to be established, there are distillation method and isotope exchange method. These two methods are used independently or in combination. An electrolytic method, a thermal diffusion method, and laser method are also known, but they are not suitable for mass process.

In this case of contaminated water at the Fukushima nuclear power station, if we try to separate tritium in the contaminated water, both high-concentration and low-concentration waste fluids will be produced. It is necessary to consider about precise goal and future processing method for these two waste fluids. In this case, we must process a large amount of waste fluid, so it will require large equipment, high cost and a long time. Especially, the risk of highly concentrated tritium is high, so there will be difficulty in managing it.

For low concentration tritiated water, it is necessary to consider the disposal method paying attention to the tritium concentration in the natural environment and the living environment and its emission limit.

Regulation and Management

Mr. Junichi Onodera, Japan Atomic Energy Agency

Under the Nuclear Reactor Regulation Law, tritium is not classified as an object of regulation by itself or subject to special regulation. It is required to manage tritium to keep the dose limit of radiation workers and the general public reckoning with internal and external exposures to other nuclides.

Under the Nuclear Reactor Regulation Law, it is defined that the effective dose limit should be 1 mSv/year around monitoring out-of-bounds area. The total amount of internal and external exposures derived from nuclear facilities should not exceed 1 mSv/year. The internal exposure to tritium is also counted in this total amount. On the other hand, on the basis of "Guideline related to dose limitation goal", nuclear power reactor facilities set 50 μSv/year or lower as the target regarding the effective dose of the public around the facility that is attributable to the radioactive materials released to the environment. In order to ensure this limitation, the annual amount of emission of each nuclide including tritium has been set and contained in safety regulation rules as effluent management goals, and observed.

In terms of the management of tritium, rapid detection and quantitative determination of tritium is difficult compared with other β-nuclides as the energy of its beta ray is low.

Experience in handling tritium in nuclear facilities

Mr. Yoshitake Shiratori, Japan Atomic Energy Agency

Tritium is produced in a nuclear reactor by neutron irradiation on moderator (heavy water), reaction control materials (boric acid) and so forth.

"Fugen", a prototype Japanese nuclear test reactor, ended its operation in 2003 after 25 years’ operation, and it is now under decommissioning. The heavy water that is used as a moderator in the "Fugen" must be always maintained at high purity, so the degraded heavy water has been purified using two kinds of devices with different principles. The concentration of tritium produced in heavy water has gradually increased during the long-term operation, and it has reached about 250 MBq/cm^3 after 25 years’ operation.

For the reductions of radiation exposure to tritium and its environmental release, countermeasures and managements have been taken on both software and hardware sides.

Small amount of heavy water that cannot be collected or reused was diluted and released into the sea. For tritium in the released heavy water, we have been always ensuring that the tritium concentration is fairly lower than the management target value prescribed in the safety regulation. The amount of tritium released from "Fugen" is low enough compared to those from heavy-water reactors in foreign countries, and equal to or less than those from light-water reactors in Japan.

In proceeding the decommissioning hereafter, we will decontaminate the remaining tritium properly, and make an effort for ensuring safety in managing the work.

Current status of contaminated water at the Fukushima Daiichi Nuclear Power Station and tritium in contaminated water

Dr. Shunsuke Uchida, a former Professor of Tohoku University

Fission products (FPs) produced by fuel melting are classified into long-term and short-term sources. FPs released to the environment just after the accident is mainly related to the short-term source. The long-term source is relating to the treatment of contaminated water, for which it is required to deal with FP elution for a long period of time.

The most fundamental countermeasure for contaminated water is to seal the water in containment vessels. Furthermore, it is essential to reduce, confine and effectively purify the contaminated water. However, the specification of the leak point and sealing the water have not yet been realized, so these are challenges for the future.

The Advanced Liquid Processing System (ALPS) and other equipment for contaminated water processing can reduce the concentration of radionuclides except for tritium to the level below the limiting value, but they cannot remove tritium.

There are three feasible methods to address tritium: 1) confinement and storage in the site of reactor, 2) removal and concentration of tritium, and 3) dilution and release. From the technological viewpoint, dilution and release under well-controlled conditions are realistic choice. These methods have technologically high reliability and small risk. In this case, two matters must be taken into account. Firstly, proper structure must be established concerning dilution and monitoring, and explanation must be sufficiently given to the local governments and other entities concerned in advance. Secondly, precaution must be taken to prevent damage by harmful rumors or misinformation as far as possible.

After the lectures, one of the audience asked, "How should we manage the tritium in the future?". Professor Konishi answered, "As the radiation of tritium is low and detected levels are always much lower than the level affecting the health, concerning the health there is no need to fear the contaminated water in Fukushima Daiichi Nuclear Power Station. The most serious problem is rather reputational damage. There are several methods for the management of the tritium. If we are to concentrate and manage tritium on earth, there is a possibility of an accident or a leakage, due to which tritium may be detected in the environment. In order to minimize the overall risk, it is necessary to reduce the radiation level of tritium detected in the environment as low as possible by dilution. In this case, however, it is essential to obtain an understanding and agreements from local residents and society."