Monitoring and management of tritium from the nuclear power plant effluent

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Abstract. It is important to regulate tritium nuclides from the nuclear power plant effluent, the paper briefly analyzes the main source of tritium, and the regulatory requirements associated with tritium in our country and the United States. The monitoring methods of tritium from the nuclear power plant effluent are described, and the purpose to give some advice to our national nuclear power plant about the effluent of tritium monitoring and management.

1. Introduction
Tritium (T) is an important resource, and it is an isotope of hydrogen, which has the same chemical properties as hydrogen. Tritium has many usages, such as using as military material (as raw materials for the hot nuclear weapons), fusion fuel, medical and scientific research, light-emitting objects (such as watches and clocks, emergency exit sign lights, airport runway lights, etc.). Tritium is a radionuclide of hydrogen, and fission, fusion and neutron activation reactions can all produce tritium. Whether natural or man-made, tritium is mobile in both the environment and biological systems. With nuclear weapons testing and the development of nuclear power plants, the concentration of tritium in the environment is increasing, and the half-life of tritium is about 12 years.

2. The main source of tritium
(1) Tritium from natural radionuclides
The tritium in the environment is very low compared to the other two isotopes of hydrogen and deuterium, and the natural tritium is mainly caused by the nuclear reaction of nitrogen and oxygen in the upper atmosphere and high energy cosmic rays. The 99% of tritium in the atmosphere is dispersed in surface water and exists in the form of tritiated water. It is about 0.15-0.20 kg (ie. 5.0-7.0* 10^16 Bq) tritiated water is produced in the atmosphere every year.

(2) Tritium from nuclear facilities
The tritium will be released into environment from the nuclear facilities such as pressurized water reactors, irradiated fuel and recycling plants and tritium production plants under normal operation and accident conditions. In pressurized water reactor, the tritium is produced through the boron(10) neutron capture, for 900 MWe reactor to produce 0.03 g (1.1 * 10^{13} Bq/yr), 1300 MWe reactor to produce 0.09 g tritium (3.2 * 10^{13} Bq/yr). In heavy water reactor, the neutron activation deuterium and produce large amounts of tritium in heavy water, each year 900 Mwe reactor produces 1.9 g (6.8 * 10^{14} Bq/yr) of tritium, and the amount of tritium is much more than light water reactor., The tritium is released from the irradiated fuel during the process of reprocessing, and tritium is detected in liquid
effluents, most of which are released into seawater. For example, at the La Hague plant, every 1,600 tons of nuclear material will release about 30g/yr (or 10^{16} Bq/yr) of tritium. Sellafield releases about 8g/yr (or 2.8 \times 10^{15} Bq/yr) of tritium.

3. The management requirement of tritium in the effluent of nuclear power plant

For emissions of radioactive substances into the environment control, it is required that the emission limits approved by national regulators are not allowed to exceed, including the limits of total emissions and concentration limits, and the emission is controlled through the proper flow rate and concentration monitoring equipment; Waste liquid containing radioactive substances using slot emissions, and must meet the annual effective dose for public exposure limit 1 msv. In particular cases, it is allowed that one year effective dose could increase to 5 msv but the annual average dose of five consecutive years is not more than 1 msv, and it is optimized that the emissions can be controlled [1].

To the dose constraint value and emission control values of the operation nuclear power plant, it is required that the effective dose to any individual caused by radioactive material from reactor is less than 0.25 msv per year. For the total emission requirements, the control value of tritium in the gas effluent is 1.5 \times 10^{15} Bq/yr (light water reactor) and 4.5 \times 10^{14} Bq/yr (heavy water reactor) for the 3000MW thermal power reactor. The control value of tritium in liquid effluent is 7.5 \times 10^{13} Bq/yr (light water reactor) and 3.5 \times 10^{14} Bq/yr (heavy water reactor) [2]. Table 1 is a list of the regulations and standards related to tritium in the effluent of nuclear power plants.

| No.  | Name                                                                 |
|------|----------------------------------------------------------------------|
| HAD102/12 | Radiation protection design of nuclear power plant                  |
| HAD103/04 | Radiation protection during operation of nuclear power plant        |
| HAD401/01 | Radioactive discharge and waste management of nuclear power plant   |
| GB18871-2002 | Basic standards of ionizing radiation protection and radiation source safety |
| GB6249-2011 | Regulations on environmental radiation protection of nuclear power plant |
| GB11217-89 | General provisions for the effluent monitoring of the nuclear facilities |
| GB/T7165.5-08 | Special requirements of tritium monitoring equipment for continuous monitoring of gaseous discharge flow (radioactivity) |
| GB14587—2011 | Technical requirements for radioactive liquid effluent of nuclear power plant |

4. Monitoring of tritium in the effluent of nuclear power plant

(1) Tritium monitoring in gaseous effluents

According to the requirements, the radioactive gaseous effluents generated by the operation of nuclear power plants need to be treated and discharged through the chimney. In the case of the Qinshan nuclear power plant, the tritium in the gaseous effluent was monitored by bubbling method, once a week. When the concentration of tritium emitted through the chimney exceeds the level of investigation, or when the emissions increase, the monitoring cycle will be shortened to three days and sometimes will be monitored every day.[5] The bubbling method is used to collect tritium from the isotope exchange of water in the two phases of the gas liquid. In addition, there is a way of continuous monitoring, namely by ionization chamber to measure, the content of tritium in effluent is determined through the average current in ionization indoor that made by the incident particles unit time. One β ionizes once in the air and forms an electron pair, and lose the energy of 34 eV. When the X-ray energy of tritium is 5.69 KeV, 1 Ci tritium generates a current of 1 \times 10^{-6} A [3]. Table 2 shows the gaseous effluent values and management limits of Qinshan nuclear power plant in 2014 and 2015. Which can be seen that the value of tritium in Qinshan nuclear power plant gaseous effluents are within the management limit.
Table 2. The content of tritium in the gaseous effluents of Qinshan nuclear power plant in 2014, 2015.

|               | 2014 (Bq) | 2015 (Bq) | management limits (Bq) |
|---------------|-----------|-----------|------------------------|
| Qinshan       | 2.79E+12  | 4.32E+12  | 5.00E+12               |
| Qinshan No.2  | 8.09E+11  | 1.60E+12  | 1.10E+13               |
| Qinshan No.3  | 8.12E+13  | 6.83E+13  | 6.16E+14               |

(2) The monitoring of tritium in liquid effluent

The two kinds of monitoring methods are generally used for the discharge of tritium wastewater from nuclear facilities: one is to continuously monitor the tritium in the liquid effluent. The other way is to regular sampling monitoring, such as the Qinshan nuclear power plant, they carry out slot discharge, before emission they will take samples to analysis, generally every batch of waste water take samples once, and then use the liquid flash analyzer analysis of tritium in the liquid effluent. [5]. Table 3 shows the tritium content in the liquid effluent value and the management limits of Qinshan nuclear power plant in 2014 and 2015, which can be seen that the tritium content in liquid effluent from Qinshan nuclear power plant are within the management limits.

Table 3. The content of tritium in the liquid effluent of Qinshan nuclear power plant in 2014, 2015

|               | 2014 (Bq) | 2015 (Bq) | management limits (Bq) |
|---------------|-----------|-----------|------------------------|
| Qinshan       | 5.86E+12  | 6.46E+12  | 6.66E+12               |
| Qinshan No.2  | 6.45E+13  | 8.33E+13  | 1.10E+14               |
| Qinshan No.3  | 6.73E+13  | 5.80E+13  | 5.04E+14               |

5. summary

In order to better control the entry environment of tritium, it should not only strengthen the monitoring of tritium water, but also control the other forms to enter the food chain. Although our country has such as GB6249, GB11217, GB14587 and other related standards, but not enough refinement, and some standards need to revise, so still need further perfect radiation environmental monitoring standard system, the refinement of relevant laws and regulations standard, make its have manoeuvrability. In addition, we also need to pay attention to the related issues of organic tritium and the relevant content of organic tritium is not considered in the existing regulations.

References

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