

Radioactive Waste Management in HANARO (High Flux Advanced Neutron Application Reactor) – 16076

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ABSTRACT

HANARO(High Flux Advanced Neutron Application Reactor) is a research reactor at the Korea Atomic Energy Research Institute (KAERI). Currently, it is the only research reactor generating a high neutron flux for neutron science and technology and the production of radioisotopes in Korea. Various kinds of radioactive wastes such as wastewater, spent ion exchange resins, solid waste and gaseous waste are generated from HANARO, as in other nuclear reactors. The most important feature of the radioactive waste in HANARO is that some radioactive waste is contaminated with tritium because HANARO uses heavy water as a reflector. At present, the waste generated from HANARO is transferred to and treated or stored at the Radioactive Waste Treatment Facility (RWTF) of KAERI. However, the RWTF does not have proper technology to treat radioactive waste contaminated with tritium from HANARO. Therefore, it is imperative to have a proper means to reduce the amount of radioactive waste and handle it more safely.

INTRODUCTION

HANARO(High Flux Advanced Neutron Application Reactor) is a 30 Mw_{th} multi-purpose research reactor generating high neutron flux(fast flux: 2.1×10^{14} n/cm²/s, thermal flux 4×10^{14} n/cm²/s) at the Korea Atomic Energy Research Institute(KAERI). The construction was completed in 1995 and the reactor reached first criticality in the same year. Normal operation is expected to last for 20 years. The features of the reactor are shown in Table I. The reactor is located in an open pool of a confinement building. It has 36 vertical holes for neutron irradiation testing, radioisotope production, neutron transmutation and the cold neutron source and 7 horizontal ports for neutron scattering instruments. The fuel is uranium silicide with a uranium enrichment of 19.75%. The coolant of the reactor is light water and the reflector (or called as moderator) is heavy water, which is stored in the tank surrounding the reactor.

TABLE I. The features of the reactor.

Type	Open-tank-in pool
Power	30 MW _{th}
Primary coolant	Light water
Fuel material	U ₃ Si
Reflector	Heavy water
Absorber	Hafnium
Max. thermal neutron flux	4 x 10 ¹⁴ n/cm ² /s
Typical neutron flux at port nose	2.1 x 10 ¹⁴ n/cm ² /s
Reactor building	Confinement building
Operation cycle	28 days @ 6weeks

Generally, four forms of waste, i.e., wastewater, spent ion exchange resins, solid waste, and gaseous waste are generated from HANARO. The most important property of waste from HANARO is that most waste is contaminated with tritium caused by the neutron capture of heavy water. Apart from gaseous waste, the radioactive wastewater, spent ion exchange resins and solid waste are transferred to and treated/stored in the Radioactive Waste Treatment Facility (RWTF) of KAERI. However, the RWTF does not have proper technology to treat the radioactive waste contaminated with tritium from HANARO. The RWTF also does not have enough space to store the waste. In addition, because the specific activity of tritium in heavy water in HANORO has gradually increased, the importance of radioactive waste management is progressively increasing from year to year. This paper reports the status of waste management in HANARO and a part of the efforts to reduce waste for the last 10 years.

RADIOACTIVE WASTEWATER

All radioactive wastewaters from the reactor building of HANARO are collected in a sump pit of 12 m³ in the same building. The wastewater in the sump pit is periodically transferred to a wastewater storage tank in the Radioisotope Production Building (RI Building), which is adjoined to the reactor building. The specific activities of radionuclides in the wastewater are analyzed prior to transfer and the result is notified to an authorized person in the RI building.

The RI building has two tanks for very low level active wastewater (less than 4 x 10⁷ Bq/m³ for tritium and less than 1.85 x 10⁵ Bq/m³ for the other nuclides), one tank for low and medium level wastewater (less than 4 x 10⁷ Bq/m³ for tritium and less than 3.7 x 10⁹ Bq/m³ for the other nuclides) and one tank for medium and high level tritiated wastewater (more than 4 x 10⁷ Bq/m³ for tritium) to store the radioactive wastewater from the RI building and the reactor building of HANARO until the stored wastewater is re-transferred to the RWTF. The storage capacity of each tank is 25 m³. The wastewater with very low to low level of activity is

periodically re-transferred to the RWTF. A very low level waste water is vaporized by air in a natural evaporation system of the RWTF and discharged into the atmosphere. For naturally evaporating the wastewater into the atmosphere, the specific activity of tritium of the wastewater is limited to less than 4×10^7 Bq/m³. Most of the wastewater generated from HANARO has a tritium activity under this limit. Low level wastewater containing tritium of less than 4×10^7 Bq/m³ is concentrated using an evaporation process in the RWTF. The condensate containing tritium from the evaporation process is vaporized in the natural evaporation system and finally discharged into the atmosphere along with very low active wastewater.

A tritiated wastewater from HANARO is stored in the tank for medium and high level tritiated wastewater. At present, its specific activity of tritium is about 2×10^9 Bq/m³ and the volume is about 20 m³. [1] Most of the wastewater was generated by an incident in 2004. Because it shouldn't be allowed to be naturally vaporized in the RWTF and there is no appropriate technology for the wastewater, it remains in the tank.

Sometimes in the field, high level tritiated wastewater has been mixed with low level tritiated wastewater. Although a small amount of high level tritiated wastewater has been mixed with a relatively large amount of low level tritiated wastewater, the low level tritiated wastewater became a medium to high level tritiated wastewater, which has too high a tritium activity to be transferred to the RWTF. However, this trivial but important matter has been overlooked for the last few years.

Therefore, the importance of a classification of wastewater was emphasized and conveyed to the engineers and operators dealing with wastewater. As a result of this effort, a mixing between low level tritiated wastewater and high level tritiated wastewater was prohibited in the field, and the amount of medium and high level tritiated wastewater was reduced considerably.

GASEOUS TRITIUM

Tritium is inevitably generated from HANARO because a part of deuterium in heavy water is converted to tritium by capturing neutrons. A change in the specific activity of tritium in heavy water with the operation time is shown in Fig. 1. The specific activity of tritium in heavy water increases as the operation time increases. As of 2014, the specific activity of tritium in heavy water reached about 360 GBq/kg.

To control and adjust the heavy water condition, HANARO has a heavy water cooling and purification system composed of circulating pumps, pipes, a heat exchanger, valves, ion exchangers, and various measuring instruments [2]. For the past decade, the specific activity of tritium in heavy water in HANARO has gradually increased due to neutron irradiation of deuterium in heavy water. Thus, to reduce the risk of tritium releasing from the heavy water cooling and purification system, HANARO built an airtight room for isolating the heavy water cooling and purification system from other places. The top views of before and after installation of the air tight room are shown in Fig. 2.

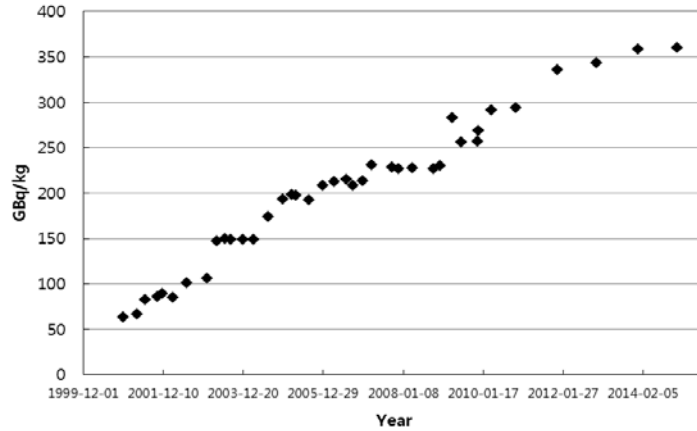


Fig. 1. A change of specific activity of tritium in heavy water during operation



Fig. 2. Top views before and after installation of air tight room

In addition, to remove the tritium in the form of water vapor in the air tight room the tritium removal system was connected to the room. The tritium removal system is shown in Fig. 3.



Fig. 3. Tritium removal system

After the installation of airtight room and tritium removal system in 2005, the annual tritium release to environment has remained constant until 2009. However, it is gradually increasing from 2010 as shown in Fig. 4.

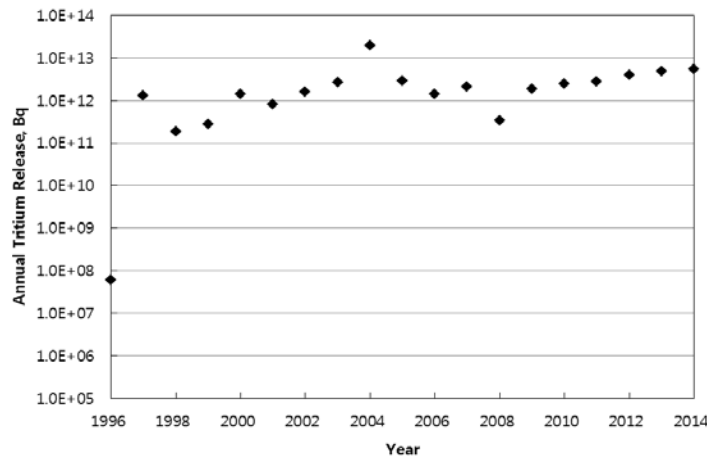


Fig. 4. Annual release of tritium from HANARO

Recently, to remove the tritium more effectively from the air tight room, the flow features of the airtight room were investigated when the tritium removal system was operating. A commercial CFD (computational fluid dynamics) code, ANSYS FLUENT(R15), was adopted to analyze the air circulation pattern inside the room.

Numerical results show that the flow strength in the airtight room is very weak, with the exception of near the inlet and outlet port regions. A velocity vector field of the air tight room is shown in Fig. 5.

Owing to feeble air circulation around the bottom region where the specific activity of tritium is relatively high, a significant amount of time is required for removing tritium from the airtight room. Based on the results, the relocation and/or extension of the suction and discharge ports near the bottom region are considered to improve the effectiveness of tritium removal from the room.

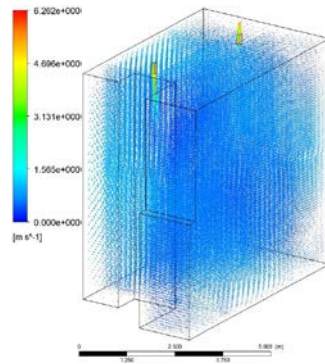


Fig. 5. A velocity vector field of air tight room

SPENT ION EXCHANGE RESINS AND SOLID WASTE

Spent ion exchange resins and solid waste are transferred to the RWTF from HANARO. Such waste is stored in a storage house of the RWTF until permanent disposal.

The following program was prepared and enforced to reduce the radioactive spent resins and solid waste since 2005. It was expected that the generation of radioactive solid waste would be reduced.

- Proper filling of ion exchange resins in the bed for preventing channeling phenomena
- Reuse of gowns and clothes by detergent-free cleaning.
- Reuse of non-radioactive waste such as papers, gloves and plastic films by a proper segregation.
- Prevention of mixing of non-radioactive waste and radioactive waste by inspection and segregation.
- Restriction of equipment, instrument, and tools, which are not necessary in a radioactive area.

The amount of spent ion exchange resins and solid wastes (combustible waste, non-combustible waste, spent filter and deregulated waste) generated in HANARO from 2005 to 2014 are shown in Fig. 6 [1].

However, the effectiveness of this program could not be quantitatively evaluated because unexpected solid waste was generated irregularly owing to the construction of new equipment in the reactor building. Nevertheless, the program is still being applied to reduce the spent resins and solid waste.

SUMMARY

The status of waste management and a part of the efforts to reduce the waste in HANARO over the last 10 years was briefly described.

Very low to low wastewater containing tritium of less than 4×10^7 Bq/m³ from HANARO is transferred to the RWTF and finally discharged into the environment using a natural evaporation system. Medium and high level tritiated wastewater containing tritium of more than 4×10^7 Bq/m³ is stored in the storage tank in the RI building owing to a lack of proper technology.

The specific activity of tritium in heavy water in HANARO has gradually increased owing to neutron irradiation of deuterium in the heavy water. Thus, to reduce the risk of tritium release into the environment, HANARO built an airtight room and a tritium removal system. After the installation of the airtight room and tritium removal system, the annual tritium release into environment has remained constant until 2009. However, it gradually increased from 2010. Recently, to more effectively remove tritium from the air tight room, the flow features of the airtight room were investigated when the tritium removal system was operating.

For the spent ion exchange resins and solid waste, a program to reduce the generation has been prepared and enforced since 2005.

Efforts to reduce the radioactive waste in HANARO are continuing and will contribute greatly to the improvement of reliability and safety of HANARO.

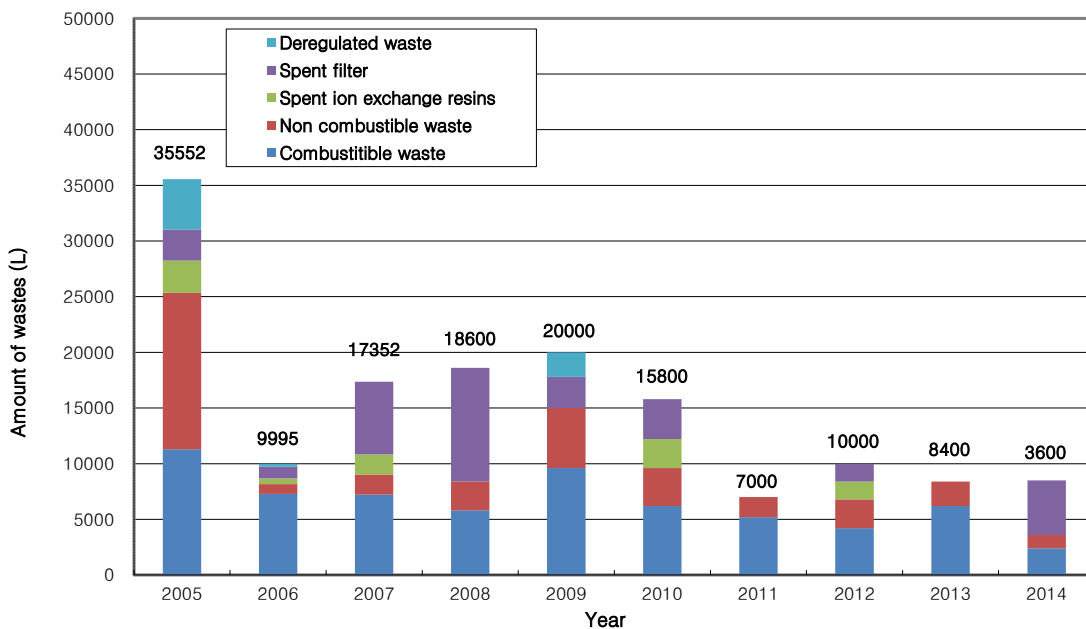


Fig. 6. Amount of spent ion exchange resins and solid waste

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2. S.P. Yim, H. S. Jung, G-H Ahn, I-C Lim, "Efforts to reduce radioactive wastes at High Flux Advanced Neutro Application Reactor (HANARO) in Korea-9190," Proceedings of WM'09 Conference, Mar. 1-March 5, Phoenix, AZ, USA (2009)