Measurements of the Efficiency of Ion Exchange Resin Used in HANARO Primary Coolant Purification System

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1. Introduction

During the normal operation of HANARO, 30 MW open-pool type research reactor, several radionuclides are dispersed in pool or coolant water. The nuclides in the water are generated by activations of coolant, dissolved substances and corrosion products. In addition, there are several fission products caused by uranium contamination on fuel cladding surface. The radionuclides disappear by radioactive decay, release out of the water, and they are also eliminated by the ion exchange resin in the coolant purification system. Thus, the information on its efficiency to remove the nuclides from the coolant is necessary to estimate the radiological effect of a research reactor. In this work, the efficiency is measured by the gamma-ray spectroscopy for the coolant of HANARO.

2. Methods

2.1 Primary coolant purification system of HANARO

HANARO has an up-flow primary cooling system. The primary coolant splits into a core flow and a bypass flow before the entrance to the core. Some of the bypass flow passes through a primary coolant purification system, and the ion exchange resin in the system cleans up ionized nuclides in the water. The resin used in the system is a nuclear grade mixed bed resin, and is a chemically balanced mixture of uniform particle size gel type cation and anion exchange resins. It is supplied in the fully regenerated H^+/OH^- form. The characteristics of the resin are shown in Table 1.

Table 1: Characteristics of ion exchange resin

Parameters	Features	
	Cation resin	Anion resin
Functional group Ionic form as shipped Total exchange capacity Harmonic mean size	Sulphonic acid H^+ ≥1.90 eq/L (H^+ form) 0.600 to 0.700 mm	Trimethylammonium OH^- ≥1.20 eq/L (OH^- form) 0.580 to 0.680 mm
Model Physical form Matrix	Amberlite™ IRN150, Rohm & Haas Spherical beads Styrene divinylbenzene copolymer	

2.2 Radionuclides in the coolant

By using the gamma-ray spectroscopy, the species and concentrations of the radionuclides in the primary coolant of HANARO are analysed [1]. The coolant is picked at the primary coolant purification system, and the cooling time is 5 minutes. So, the short-lived activation products like N-16 were not detected in the gamma-ray spectrum. Table 2 shows the measured activity concentrations of several representative nuclides in the coolant water. In order to determine the cleanup efficiency of the ion exchange resin, the coolant water samples were collected at the ion exchanger inlet and outlet

Table 2: Measured activity concentrations of several representative nuclides in the coolant water

Nuclide	Concentration [Bq/liter]
Al-28	1.75×10^6
Ar-41	3.15×10^5
Cs-138	2.56×10^4
I-132	7.17×10^3
Mg-27	5.25×10^6
Na-24	1.54×10^6
Xe-133	9.32×10^3

Concentrations of Na-24, Mg-27 and Al-28 are higher than those of other nuclides in the coolant. Their origins are radiative reactions of the aluminum used as the structural material in the reactor core and the irradiation rigs and the cladding of the nuclear fuel. Ar-41 is generated from the activation of dissolved air.

In addition, many fission products such as iodine and xenon nuclides were detected in the coolant. Among them, the concentrations of Cs-138, I-132 and Xe-133 were relatively higher than those of others. The source of the fission fragments in the coolant is the surface contamination of the nuclear fuel by uranium [2].

3. Results

Table 3 shows the measured cleanup efficiencies of the ion exchange resin for Na-24 and Mg-27. For several fission fragment ions, the measurements of the efficiency did not show consistent values due to the large uncertainty, and further study will be continued. At any rate, since Na-24 and Mg-27 are the main radionuclides in the coolant water, the efficiencies for two nuclides were deduced. The concentration of the Al-28 is also relatively high, but it decays very fast due to its short half-life. As shown in the table, no noticeable difference between Na-24 and Mg-27 was found. Therefore, it can be assumed that the cleanup efficiency of the resin is about 0.9 for Na-24 and Mg-27.

The activity of Ar-41 at the ion exchanger outlet was almost the same as at the inlet. Thus, the efficiency for the noble gas can be considered to be 0.

Table 3: Measured cleanup efficiency of the ion exchange resin for Ma-24 and Mg-27

Date	Cleanup efficiency	
	Na-24	Mg-27
2009-01-02	0.845	0.845
2009-01-30	0.899	0.975
2009-03-05	0.905	0.915
2009-03-11	0.915	0.916
2009-03-22	0.917	0.904
2009-04-10	0.916	0.896
2009-04-17	0.920	0.914
2009-04-22	0.917	0.907

Fig. 1 shows the comparison of the coolant conductivity and the ratio of measured activity concentrations at the inlet and outlet of the ion exchanger.

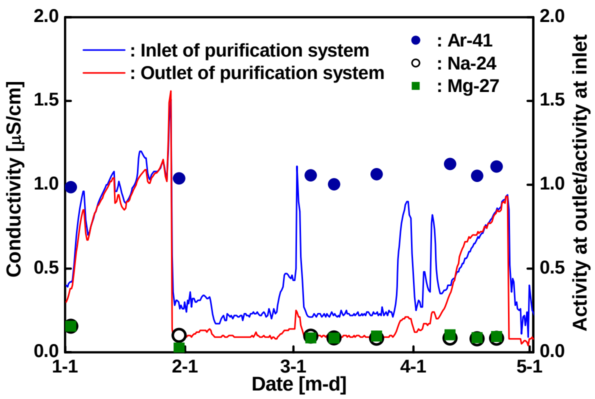

Fig. 1. Comparison of the coolant conductivity and the ratio of activity measurements at the inlet and outlet.

Coolant conductivities at the inlet and outlet of the ion exchanger are almost steady while the ion exchanger is working normally, and they increase rather rapidly when the resin reaches the end of its lifespan. As shown in the figure, the conductivity of the coolant does not have any relation to the performance of the ion exchange resin. It means that the contribution of the radioactive ions to the conductivity is much smaller than that of the non-active ions such as H^+, OH^-, etc.

4. Conclusion

The cleanup efficiency of the ion exchange resin of the HANARO primary coolant purification system was measured by gamma-ray spectroscopy. The efficiency of the resin is about 0.9 for Na-24 and Mg-27 which are the representative radioactive ions. The efficiency for the noble gas can be considered to be 0. The conductivity of the coolant does not have any relation to the performance of the ion exchange resin. The results will be useful to estimate the radiological effect of the research reactor.

REFERENCES

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[2] Myong-Seop Kim, Byung-Chul Lee, Sang-Jun Park, Byung-Jin Jun, Sensitivity of Fuel Failure Detection by the Delayed Neutron Measurement in the Primary Cooling Circuit of HANARO, Annals of Nuclear Energy, Vol.33, p.1134, 2006.