OPERATIONAL RESULTS OF RADIONUCLIDE ASSAY SYSTEM AT THE KORI NUCLEAR POWER PLANT: STATUS AND RESULTS

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ABSTRACT

At the year of 1996, the fully automated radionuclide assay system, which is used for the non-destructive analysis and for the evaluation of radioactive waste drums, was installed at Kori nuclear power plant site and started to operate. The system is composed of gamma scanning hardware facility, equipment for separation and detection of non-gamma radionuclide, scaling factor prediction program, and control facility for radionuclide assay system. In this study, the operational status and results of radionuclide assay system are investigated from the experience of several years of operation. The results of the radionuclide assay system are compared with the results of dose to curie conversion program (DOSE).

1. Introduction

Nuclear Act of Korea recently requires the manifest of low and intermediate level radioactive waste (LIRW) generated at Korean Nuclear Power Plant (NPP). Historical records of the individual radioactive waste drums should contain the detailed information such as activity of radionuclides, total activity, weight and the physical type of the waste contained.

Measurement of concentration and total activity of radionuclide contained in radwaste drum is very important for the accurate management of radioactive waste in NPP. To achieve this critical purpose, nondestructive prediction methods are world-widely suggested for last twenty years in the aspects that it makes possible reduction of radiation exposure for workers and reliability of measurement. [1-6]

At the end of 1993, Korea Electric Power Research Institute (KEPRI) organized the scheduled project to design and install the radioactive waste assay system with partial cooperation of Korea Atomic Energy Research Institute (KAERI) and Korea Advanced Institute of Science and Technology (KAIST).

There were various kinds of discussions among three research institutes and modifications of project products during thirty months including: 1) collection of the data for non-destructive assay, 2) collection and analysis of the operational history of NPP, 3) development of non-destructive assay technique for the measurement of the radioactivity emitted from various radwaste streams, 4) design of model drum to evaluate assay system, 5) development of the integrated control program for radioactive waste assay system, 6) development of chemical analysis method of radioactive waste with the waste sampling technique, 7) development of scaling factor determination program and 8) establishment of the normal and abnormal operation guide of radioactive waste assay system [7-15].

Kori NPP was selected as the candidate site for utilization and installation of this project. Radionuclide assay system was installed and started to operation at the mid of 1996. The operational results are shown in this study and the comments for the non-destructive assay system are suggested for the next-generation radionuclide assay system in Korea.

2. Status of Radionuclide Assay System at Kori NPP

Radionuclide assay system was designed, manufactured and installed at Kori NPP in order to reduce worker exposure and to measure the total activities of homogeneous and non-homogeneous waste. This system was designed to calculate total activities of waste drum with scaling factors by measurement of the representative gamma-emitting radionuclides such as Co-60 and Cs-137.

Dividing a waste drum into eight vertical segments and eight radial sectors in each vertical sector, both the activities of homogeneous and non-homogeneous waste drum were measured by this system using matrix correction method such as transmission ratio, differential peak absorption and mean waste density correction, independently or together.

Optimum operating condition of this system was determined by evaluation of affecting factors on the measurement of activity. The measurement error was about 10% for standard gamma sources 1 and was less than 30% for standard gamma source 2, located in the center of model drum with density of 1.1 g/cc.

Radiochemical analysis procedures were established for each waste stream and for target nuclides. Scaling factor determination program was developed based on RADSOURCE [6] for the calculation of the concentration ratio between hard to measure nuclide and easy to measure nuclide. It was found that validation procedure of calculated scaling factor was highly correlates with data from radiochemical separation and detection procedure of radwaste samples [15]. Fig. 1 shows the comparison of scaling factors between the predicted and the measured values. Monitoring system was installed to manage the operational status of the integrated assay system in the control room.

3. Operational Results of Radionuclide Assay System

To show the operational results of radionuclide assay system, some of activity data sheets, were collected and interpreted from 4 units of power plant at Kori. Table 1 summarizes the information of activity data sheets collected from the years of 1998 to 2000 including detailed numbers and corresponding locations of drum generation at the Kori site.

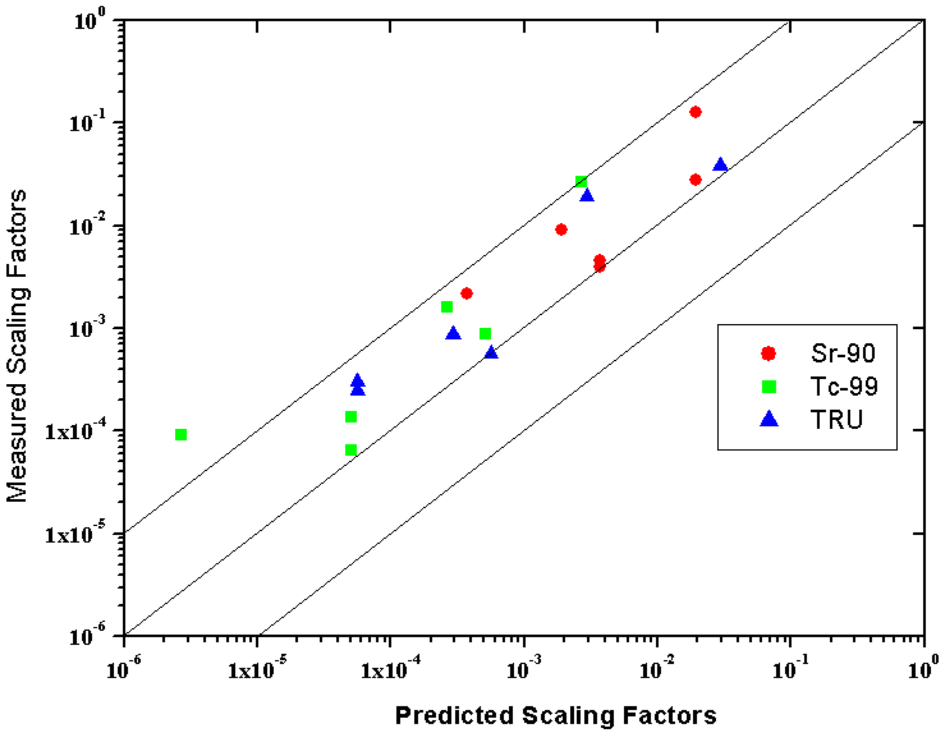

Figure 1. Comparison of scaling factors between the predicted and the measured values [12]

Table 1. Information on drum activity sheets and location of drum generation

	Dry Active Waste		Concentrate Bottom	Spent Filter
	Without concrete shielding	With concrete shielding		
Unit# 1	754	24	33	-
Unit# 2	425	86	-	2
Unit# 3	193	9	-	3
Unit# 4	358	48	-	2
Radwaste	125	7	84	7

Non-gamma radionuclides in activity data sheet are H-3, C-14, Ni-63, Nb-94, Fe-55, Sr-90, Tc-99 and Gross alpha. The other information than radionuclide activity are as follows; obtained the name of operator, drum identification code, surface dose rate, drum weight, detection date and activities of gamma radionuclides (Co-60, Cs-137, Mn-54, Ag-110m, Cs-134, Ce-141, Nb-95, Cr-51, Zr-95, Ce-144, Fe-59, Rb-86, Ru-103, Ba-140, Zn-65 and Sb-125).

Table 2 shows statistical results for radionuclide activity of DAW without concrete shielding generated at the Kori site. Mean concentration of activity was decreased in the order of Ni-63, Fe-55, H-3, C-14, Sr-90, alpha-emitting TRU, Tc-99 and Nb-94. Table 3 is the results for the DAW with concrete shielding. The decreasing order of activity is same with Table 2. However, the magnitudes of radionuclide activity in Table 3 are approximately 40% times higher than those of activity in Table 2. Especially for Sr-90, Tc-99 and alpha emitting TRU, the activities of Unit 1 and 2 show apparently higher values than those of Unit 3 and 4 in Table 2 and

Table 3.

Table 4 is the results for drums containing concentrated waste from bottoms of evaporator bottom and spent filters. Due to relatively small number of activity data , spent filter is collected and interpreted together from all NPP units of Kori site . Order of activity magnitude was found to be different with Table 2 and 3 in Table 4. At the concentrate bottom of Unit 1, activity of H-3 shows higher activity than that of Fe-55. For spent filter, radionuclide inventory is slightly different when it is compared with DAWs and concentrate bottoms. All of the activity report is marked based on the unit of Bacquerel, Bq.

Table 2. Statistical result of radionuclide activity of DAW without concrete shielding

Nuclides	Drum	Dry Active Waste (Unit : Bq/drum)				
	Unit	Unit # 1	Unit # 2	Unit # 3	Unit # 4	Radwaste
H-3	mean	7.74E+06	6.11E+06	1.31E+07	1.94E+07	1.55E+07
	maximum	6.40E+08	8.40E+07	1.70E+08	6.50E+08	1.50E+08
C-14	mean	6.51E+06	5.24E+06	1.03E+07	1.54E+07	1.23E+07
	maximum	5.10E+08	6.90E+07	1.30E+08	5.20E+08	1.20E+08
Ni-63	mean	1.55E+07	1.19E+07	2.85E+07	4.22E+07	3.35E+07
	maximum	1.40E+09	1.80E+08	3.70E+08	1.40E+09	3.20E+08
Nb-94	mean	3.76E+03	3.07E+03	3.01E+03	7.68E+03	6.76E+03
	maximum	2.80E+05	4.20E+04	8.20E+04	2.80E+05	6.40E+04
Fe-55	mean	1.71E+07	1.39E+07	1.36E+07	3.48E+07	3.06E+07
	maximum	1.30E+09	1.90E+08	3.70E+08	1.30E+09	2.90E+08
Sr-90	mean	7.28E+05	1.11E+06	3.24E+04	3.73E+04	7.37E+05
	maximum	1.10E+08	7.10E+07	2.80E+06	5.00E+06	2.70E+07
Tc-99	mean	6.46E+04	9.88E+04	2.86E+03	3.26E+03	1.61E+05
	maximum	9.90E+06	6.20E+06	2.50E+05	4.40E+05	5.90E+06
TRU	mean	3.14E+05	4.76E+05	1.39E+04	1.63E+04	3.79E+05
	maximum	4.90E+07	3.10E+07	1.20E+06	2.20E+06	1.40E+07

Table 3. Statistical results of radionuclide activity of DAW with concrete shielding

Nuclides	Drum	Dry Active Waste (with concrete shielding) (Unit : Bq/drum)				
	Unit	Unit # 1	Unit # 2	Unit # 3	Unit # 4	Radwaste
H-3	mean	5.71E+09	2.09E+09	4.41E+09	4.11E+09	2.59E+10
	maximum	2.20E+10	2.70E+10	1.40E+10	3.80E+10	6.10E+10
C-14	mean	4.80E+09	1.70E+09	3.47E+09	3.31E+09	2.10E+10
	maximum	1.80E+10	2.20E+10	1.10E+10	3.00E+10	4.90E+10
Ni-63	mean	1.16E+10	4.46E+09	9.46E+09	8.96E+09	5.64E+10
	maximum	4.90E+10	5.90E+10	3.00E+10	8.20E+10	1.30E+11
Nb-94	mean	2.75E+06	9.39E+05	1.44E+05	79645.8333	1.16E+07
	maximum	9.80E+06	1.20E+07	8.90E+05	1.30E+06	2.70E+07
Fe-55	mean	1.25E+10	4.27E+09	6.47E+08	3.63E+08	5.17E+10
	maximum	4.40E+10	5.40E+10	4.00E+09	6.00E+09	1.20E+11
Sr-90	mean	1.28E+08	3.46E+09	1.48E+04	1.15E+07	3.49E+07
	maximum	6.70E+08	7.60E+10	1.10E+05	5.20E+08	2.10E+08
Tc-99	mean	1.25E+07	3.05E+08	1.30E+03	1.02E+06	7.48E+06
	maximum	5.90E+07	6.60E+09	9.70E+03	4.60E+07	4.50E+07
TRU	mean	5.03E+07	1.51E+09	6.43E+03	5.09E+06	1.82E+07
	maximum	2.90E+08	3.30E+10	4.80E+04	2.30E+08	1.10E+08

Table 4. Statistical results of radionuclide activity of concentrated waste from bottoms of evaporator and spent filters

Nuclides	Drum	Concentrate Bottom (Unit : Bq/drum)		Spent Filter
	Unit	Unit # 1	Radwaste	
H-3	mean	3.39E+09	9.72E+08	9.66E+08
	maximum	3.80E+10	9.60E+09	2.40E+09
C-14	mean	1.84E+08	7.74E+08	3.10E+09
	maximun	2.20E+09	7.70E+09	1.20E+10
Ni-63	mean	3.19E+09	2.12E+09	7.79E+09
	maximum	3.70E+10	2.10E+10	2.80E+10
Nb-94	mean	4.04E+05	4.27E+05	1.55E+06
	maximun	4.70E+06	4.20E+06	4.80E+06
Fe-55	mean	3.65E+08	1.93E+09	7.05E+09
	maximum	2.00E+09	1.90E+10	2.20E+10
Sr-90	mean	5.30E+08	1.28E+07	5.18E+06
	maximun	1.60E+10	3.20E+08	4.80E+07
Tc-99	mean	3.67E+06	2.78E+06	4.85E+05
	maximum	1.10E+08	7.00E+07	4.00E+06
TRU	mean	4.67E+07	6.46E+06	1.11E+06
	maximun	1.40E+09	1.60E+08	9.20E+06

To guarantee the quality assurance of this system, radionuclide concentrations of non-gamma nuclides reported by this system are analyzed and compared with those obtained from dose to curie conversion program called DOSE [12]. Program DOSE was simply designed with surface dose per unit curie, curie ratio of non-gamma radionuclide and scaling factors. Surface dose per unit curie and curie ratio was calculated from calculated MCNP simulations with detailed physical drum information. Scaling factor was generated by the radiochemical detection procedure in DOSE program.

10 radioactive waste drums are selected to compare the activity date between radionuclide assay system and dose to curie conversion program. 3 waste drums are DAWs with concrete shielding (high activity) generated from Unit 4 and 7 waste drums are DAWs without concrete shielding (low activity) generated from Unit 1.

Fig. 2 shows this validation effort of radionuclide assay system by comparison between the plot of activity from radionuclide assay system vs. dose to curie conversion program. DOSE. The results of alpha emitting TRU radionuclides was not includes in the plots.

Among 70 values of radionuclides, the activity data for Nb-94, Fe55, Sr-90 and Tc-99 are not generated from 3 concrete shield drums with high activity in DOSE program whereas the 2 values for Nb-94 and 4 values for in Tc-99 are not generated from Radionuclide assay system. Therefore, 56 values [70 – (3*4 + 2 + 4)] are plotted in Fig. 2. It was found that 78% of plotted values are agreed each other within ten times deviation range. . Radionuclides such as Ni-63 and H-3 of 3 concrete shielded drums are not agreed within the range.

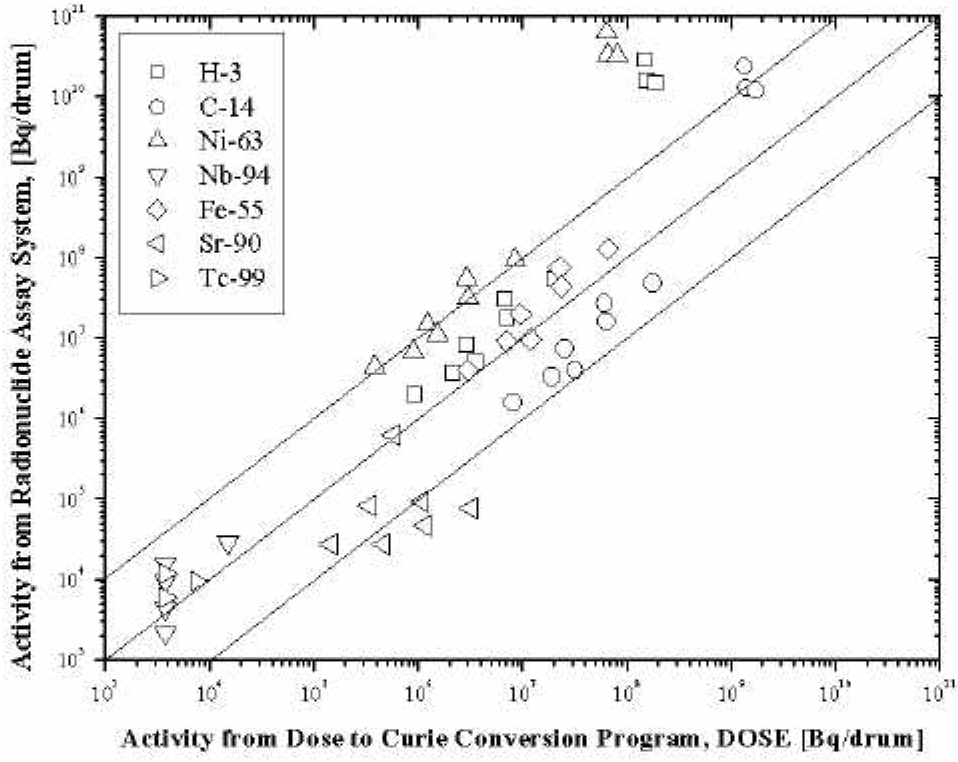

Figure 2. Comparison between activity from radionuclide assay system and that from dose to curie conversion program, DOSE

4. Conclusions

Radionuclide assay system installed and operated since 1996 at Kori NPP was evaluated in respect of operating condition and the results of analysis. The drum data chosen from random sampling was statistically handled and the activity of radionuclide of DAW was found to be decreased in the order of Ni-63, Fe-55, H-3, C-14, Sr-90, alpha-emitting TRU, Tc-99, and Nb-94. The level of radioactivity from the waste with concrete shielding was 40 % higher than the level of the unshielded waste. The DAW from each NPP sites at Kori was found to have different level of radioactivity and the concentrated waste from bottoms of evaporator and the drum of spent filter have different compositions and concentrations of radionuclides.

The validation of radionuclide assay system was performed by comparison with the results from DOSE program. About 78 % of radionuclide assay data were highly correlated with the calculated values from DOSE. Radionuclide assay data for Ni-63 and H-3 found in DAW with concrete shielding were more deviated from the correlation.

The capability of radionuclide assay system was examined for the analysis of radioactive waste drums in this study. It is suggested that collection of more data from frequent sampling should be carried out to confirm the comparison results with conventional DOSE data. The performance of this study would be presumably reflected in manufacturing, installation, and operation of next generation radionuclide assay system.

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