Study on the Prediction of the Quantity of Low and Intermediate Level Radioactive Wastes generated with Considerations for the Changes in Domestic Nuclear Power Generation policies

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1. Introduction

The 7th and the 8th Basic Plans for the Demand and Supply of Electric Power, in addition to plans for the execution of low and intermediate level waste control in 2016 and 2018, predicted the generation quantity by the nuclear power plants planned in accordance with the energy conversion policies as well as the forecast for the generation of radioactive wastes until the time the nuclear power plants are finally decommissioned.

Through this study, the quantity of radioactive wastes generated at the nuclear power plants' final closure time was predicted more accurately by analyzing the actual operation of the nuclear power plants, as was the quantity of waste generation from decommissioning and non-nuclear power plant wastes, etc., as well as the time period of the generation thereof per annum with considerations for the continuous policy changes.

2. Standards for the Computation of the Forecast on the Radioactive Waste Generated

It was presumed that the annual waste generation quantity is 100 drums for each nuclear power plant in operation (Plant No.), 14,500 drums at the time of nuclear power plant decommissioning (Plant No.), and 364 drums of KAERI, 350 drums of KNFC, and 33 drums of RI wastes in the case of non-nuclear power plants in accordance with the Basic Plan for the Demand and Supply of Electric Power.

. Table I: Standards for the forecasted computation of radioactive wastes generated

(Unit: Drums/annum*Plant No.)

Categories	Nuclear power plants		Non-nuclear power plants		
	Nuclear power plants in operation	Nuclear power plant decommissioning	RI	KAERI	KNFC
Quantity generated	100	14,500*	33	364	350

* Decommissioning of Nuclear Facilities (OECD NEA, 1991)

2.1 Operational Radioactive wastes

1. Nuclear power plants in operation: No. of nuclear power plants in operation x Annual quantity generated for each plant x Lifespan = Anticipated quantity of operational wastes to be generated

The annual quantity generated for each plant is 100 drums, and the computation of the total quantity of wastes to be generated is possible by applying the designed lifespan of each nuclear power plant as specified in the Basic Plan for the Demand and Supply of Electric Power.

2.2 Decommissioning Radioactive wastes

The quantity of wastes generated at the nuclear power plant decommissioning time, with consideration for the power plant capacities on the basis of those of 900 ~ 1,300MWe PWR nuclear power plants, can be predicted by using the following equation:

$$Quantity\ of\ waste = WA_{Cf} \times \left(\frac{C_i}{C_{i_{ref}}}\right)^{0.6}$$

WA_{ref}: Reference quantity of generation
C_i: Capacity of subject nuclear power plant (MWe)
C_{ref}: Standard Capacity (MWe)

2.3 Non-nuclear power plant Radioactive wastes

1. KAERI: Annual quantity generated (364 drums) x Period until the final decommissioning of nuclear power plants
2. KNFC: Annual quantity generated (350 drums) x Period until the final decommissioning of nuclear power plants
3. RI wastes: Annual quantity generated (33 drums) x Period until the final decommissioning of nuclear power plants

3. Analysis of the Existing Basic Plan for Electric Power Supply and Demand

3.1 The 7th Basic Plan for the Demand and Supply of Electric Power

3.1.1 Current status of low and intermediate level radioactive wastes generated

As of the end of 2015, low and intermediate level radioactive wastes generated included 98,887 drums from nuclear power plants in operation, 20,576 drums of KAERI, 7,695 drums of KNFC, 3,099 drums of RI wastes, and 1,496 drums of others (waste ascon), for a grand total of 131,723 drums.

Table II: Status of low and intermediate level radioactive wastes generated (as of the end of 2015)

(Unit: Drums)

	Nuclear power plants in operation	KAERI	KNFC	RI	Others (waste ascon)
Quantity generated	98,887	20,576	7,695	3,099	1,496

3.1.2 Forecast for low and intermediate level radioactive wastes generated (2016)

The quantity generated for each level of radioactivity in accordance with the radioactive waste classification standards was predicted for the 36 nuclear power plant units as per the 7th Basic Plan for the Demand and Supply of Electric Power.

Regarding the results, it was forecasted that a total of 835,000 drums of wastes, including 216,887 drums of operational nuclear power plant wastes, 522,000 drums of decommissioning wastes, and 96,331 drums of non-nuclear power plant wastes will be generated until 2100, at which time the nuclear power plants will be finally dismantled.

3.2 The 8th Basic Plan for the Demand and Supply of Electric Power

3.2.1 Current status of low and intermediate level radioactive waste quantities generated

A total of 138,432 drums of low and intermediate level radioactive wastes was generated as of the end of 2017, including 102,852 drums from nuclear power plants in operation, 23,628 drums from KAERI, 8,425 drums from KNFC, 2,031 drums of RI wastes, and 1,496 drums of others (waste ascon).

Table III: Status of low and intermediate level radioactive wastes generated (as of the end of 2017)

(Unit: Drums)

	Nuclear power plants in operation	KAERI	KNFC	RI	Others (waste ascon)
Quantity generated	102,852	23,628	8,425	2,031	1,496

3.2.2 Forecast for low and intermediate level radioactive wastes generated (2018)

The quantity generated for each level of radioactivity in accordance with the radioactive waste classification standards was predicted for the 30 nuclear power plant units as per the 8th Basic Plan for the Demand and Supply of Electric Power. Standards for the forecasted computation of radioactive wastes generated are the same as those of the existing standards from 2016.

Regarding the results, it was forecasted that a total of 708,000 drums of wastes, including 179,452 drums of operational nuclear power plant wastes, 435,000 drums of decommissioning wastes, and 93,099 drums of non-nuclear power plant wastes will be generated until 2094, at which time the nuclear power plants will be finally dismantled.

4. Computation of the Anticipated Quantity Generated through the Analysis of the Basic Plan for the Demand and Supply of Electric Power

4.1 The 7th Basic Plan for the Demand and Supply of Electric Power

4.1.1 Computation of the anticipated quantity of radioactive wastes generated through analysis of existing policies

The quantity of low and intermediate level radioactive wastes generated until the termination of nuclear power plant operation was recomputed by considering the computational standards for the forecasted and radioactive wastes generated until the end of 2015, as well as any additionally necessary presumptions, and it is illustrated below in Table IV.

The termination year of nuclear power plant operation has been projected to be 2103 for the 2 new nuclear power plant units (unconfirmed), and the anticipated total quantity of waste generation is predicted to be 839,694 drums. This is greater than the waste quantity that can be accommodated by the Gyeongju treatment plant scheduled to be constructed with a total capacity of 800,000 drums. According to the forecasted results for the anticipated quantity generated per annum, it has been found that the aforementioned treatment plan will reach full saturation with a total 790,932 drums by 2094.

4.2 The 8th Basic Plan for the Demand and Supply of Electric Power

4.2.1 Computation of the anticipated quantity of radioactive wastes generated through analysis of existing policies

The quantity of low and intermediate level radioactive waste generated until the termination of nuclear power plant operation was predicted by considering the computational standards for the forecasted quantity of wastes and radioactive wastes generated until the end of 2017, as well as any additionally necessary presumptions, and it is illustrated below in Table V.

The termination year of nuclear power plant operation has been projected to be 2098 for the Singori Nuclear Power Plant No. 6, counted among the total of 30 nuclear power plant units, and the anticipated total quantity of waste generation is predicted to be 711,079 drums.

Due to the nullification of the plans to construct 6 new nuclear power plant units, cessation of the lifespan extension of 10 aged nuclear power plants (Gori units 2, 3, and 4, Hanbit units 1 and 2, Wolsong units 2, 3, and 4, and Hanul units 1 and 2), and reflective exclusion of Wolsong Plant No. 1's power supply as of the end of 2018 in accordance with the public announcement of the confirmation of the 8th Basic Plan for the Demand and Supply of Electric Power in comparison to the number of nuclear power plants in operation and planned under the 7th Basic Plan for the Demand and Supply of Electric Power, the final decommissioning time of the nuclear power plants has been reduced, and as such, the quantity generated has decreased.

Table IV: Computation of the anticipated quantity of waste generated through the 7th Basic Plan for the Demand and Supply of Electric Power

The 7th Basic Plan for the Demand and Supply of Electric Power[1)]					
Nuclear power plants[2)]	Operational wastes	1. Quantity of operational wastes generated prior to 2016: 98,958 drums 2. Quantity of operational wastes generated after 2016: 119,929 drums 3. Total quantity of operational wastes generated: 218,087 drums[3)]	Anticipated quantity generated		
				Quantity generated (drum)	Ratio (%)
			Intermediate level	13,739 drum	6.3%
			Low level	180,576 drum	82.8%
			Very-low level	23,771 drum	10.9%
			Total	218,087 drum	100%
	Decommissioning wastes[4)]	1. Quantity of decommissioning wastes generated until 2103: 522,288 drum6)	Anticipated quantity generated		
				Quantity generated (drum)	Ratio (%)
			Intermediate level	21,936 drum	4.2%
			Low level	149,897 drum	44.6%
			Very-low level	350,455 drum	50.6%
			Total	522,288 drum	100%
Non-nuclear power plants		1. Quantity of non-nuclear power plant wastes generated prior to 2016: 32,836 drums 2. Quantity of non-nuclear power plant wastes generated after 2016: 63,495 drums 3. Total quantity of non-nuclear wastes generated: 99,319 drums[6), 7)]	Anticipated quantity generated		
				Quantity generated (drum)	Ratio (%)
			Intermediate level	6,020 drum	6.3%
			Low level	79,130 drum	82.8%
			Very-low level	10,417 drum	10.9%
			Total	96,331 drum	100%
Total anticipated quantity generated		1. Quantity of wastes generated at the time of termination of nuclear power plant operation: 839,694[8)]	Anticipated quantity generated		
				Quantity generated (drum)	Ratio (%)
			Intermediate level	41,933 drum	5.0%
			Low level	412,709 drum	49.0%
			Very-low level	385,053 drum	46.0%
			Total	839,694 drum	100%

1) Prepared based on the 7th Basic Plan for the Demand and Supply of Electric Power (utilized the ratio values of the execution plan for the ratios of each waste radioactivity level)
2) Nuclear power plants: When a total of 36 nuclear power plant units are operated, 100 drums/year*unit, and at the time of decommissioning, 14,500 drums for each plant will be generated. Refer to the Decommissioning of Nuclear Facilities (OECD NEA, 1991) for decommissioning waste generation quantities.
3) Quantity of operational waste generated under the execution plan: 216,887 drums (error range: 1,200 drums); this error is due to the presumption of the generation of 100 drums during the final operational year of each nuclear power plant.
4) Nuclear power plant decommissioning period: Total of 15 years (2 years of preparation prior to permanent operational stoppage, 5 years for nuclear fuel cooling after use, 6 years for decontamination and decommissioning, and 2 years for land restoration). However, decommissioning waste generation is presumed to take 13 years out of the total of 15 years with the exclusion of 2 years for preparation prior to permanent operational stoppage.
5) Quantity of decommissioning waste generated under the execution plan: 522,000 drums (error range: 288 drums); this error is due to the computation of 14,500 drums/13 years = 1,116/year (fractional values were rounded up)
6) Non-nuclear power plants: KAERI: (364 drums/year), KNFC: (350 drums/year), RI: (33 drums/year), there is an increase in the quantity of waste generated in accordance with the application of the year 2103, rather than 2100, as the nuclear power plant decommissioning year.
7) Others wastes (waste ascon) are presumed not to be generated after 2017.
8) The quantity of waste generated at the nuclear power plant decommissioning time under the execution plan: 835,218 drums (error range: 4,476 drums)

Table V: Computation of anticipated quantity of waste generated through the 8th Basic Plan for the Demand and Supply of Electric Power

The 8th Basic Plan for the Demand and Supply of Electric Power[1)]					
Nuclear power plants[2)]	Operational wastes	1. Quantity of operational wastes generated prior to 2018: 102,852 drums 2. Quantity of operational wastes generated after 2017: 76,900 drums 3. Total quantity of operational wastes generated: 179,752 drums[3)]	Anticipated quantity generated		
				Quantity generated (drum)	Ratio (%)
			Intermediate level	11,324 drum	6.3%
			Low level	146,318 drum	81.4%
			Very-low level	22,109 drum	12.3%
			Total	179,752drum	100%
	Decommissioning wastes[4)]	1. Quantity of decommissioning wastes generated until 2098: 435,240 drums[5)]	Anticipated quantity generated		
				Quantity generated (drum)	Ratio (%)
			Intermediate level	18,280 drum	4.2%

			Low level	124,914 drum	28.7%
			Very-low level	292,046 drum	67.1%
			Total	435,240 drum	100%
Non-nuclear power plants		1. Quantity of non-nuclear power plant wastes generated prior to 2016: 32,836 drums 2. Quantity of non-nuclear power plant wastes generated after 2016: 63,495 drums 3. Total quantity of non-nuclear wastes generated: 99,319 drums[6), 7)]	Anticipated quantity generated		
				Quantity generated (drum)	Ratio (%)
			Intermediate level	6,020 drum	6.3%
			Low level	79,130 drum	82.8%
			Very-low level	10,417 drum	10.9%
			Total	96,087 drum	100%
Total anticipated quantity generated		1. Quantity of wastes generated at the time of termination of nuclear power plant operation: 839,694 drum[8)]	Anticipated quantity generated		
				Quantity generated (drum)	Ratio (%)
			Intermediate level	35,624 drum	5.0%
			Low level	350,792 drum	49.7%
			Very-low level	324,629 drum	45.3%
			Total	711,079 drum	100%

1) Prepared based on the 8th Basic Plan for the Demand and Supply of Electric Power (utilized the ratio values of the execution plan for the ratios of each waste radioactivity level)
2) Nuclear power plants: When a total of 30 nuclear power plant units are operated, 100 drums/year*unit, and at the time of decommissioning, 14,500 drums for each plant will be generated. Refer to the Decommissioning of Nuclear Facilities (OECD NEA, 1991) for decommissioning waste generation quantities.
3) Quantity of operational waste generated under the execution plan: 179,452 drums (error range: 300 drum); this error is due to the presumption of the generation of 100 drums during the final operational year of each nuclear power plant.
4) Nuclear power plant decommissioning period: Total of 15 years (2 years of preparation prior to permanent operational stoppage, 5 years for nuclear fuel cooling after use, 6 years for decontamination and decommissioning, and 2 years for land restoration). However, decommissioning waste generation is presumed to take 13 years out of the total of 15 years with the exclusion of 2 years for preparation prior to permanent operational stoppage.
5) Quantity of decommissioning waste generated under the execution plan: 435,240 drums (error range: 240 drums); this error is due to the computation of 14,500 drums/13 years = 1,116/year (fractional values were rounded up).
6) Non-nuclear power plants: KAERI: (364 drums/year), KNFC: (350drums/year), RI: (33drums/year), there is an increase in the quantity of waste generated in accordance with the application of the year 2098, rather than 2100, as the nuclear power plant decommissioning year.
7) Others wastes (waste ascon) are presumed not to be generated after 2017.
8) The quantity of waste generated at the nuclear power plant decommissioning time under the execution plan: 711,079 drums (error: 3,528 drums).

5. Conclusion

According to the current Basic Plan for the Demand and Supply of Electric Power, the Gyeongju Treatment Plant has planned for the treatment of a total of 800,000 drums of low and intermediate level radioactive wastes.

As it is anticipated that decommissioning wastes for each of the diversified radioactivity levels will be generated through the decommissioning of the Gori Nuclear Power Plant No. 1 in earnest, it is necessary to establish an efficient strategy for treatments thereof. In addition, it is deemed to be beneficial to the specific means of operation of the additional stage 3 and 4 treatment facilities with considerations for the operational statuses of the treatment facilities in their 1st and 2nd stages.

In this study, the anticipated quantity of waste generation was computed though the analysis of the Basic Plan for the Demand and Supply of Electric Power and the execution plan. As such, the total anticipated quantity of waste generated, including operational wastes, decommissioning wastes, and non-nuclear power plant wastes, until the nuclear power plant decommissioning times were computed on the basis of the computational standards and presumptions necessary for the computation of the anticipated quantity of wastes generated.

REFERENCES

[1] Korea Radioactive Waste Agency, Management plan for Low-and Intermediate-Level Radioactive Waste (2016)
[2] Korea Radioactive Waste Agency, Management plan for Low-and Intermediate-Level Radioactive Waste (2018)
[3] 7th Basic Plan for Long-term Power Supply and Demand (2015)
[4] 8th Basic Plan for Long-term Power Supply and Demand (2017)
[4] K.Y. Suk, “A Study on the Alternative Reducing Measures and Decommissioning Costs of Large Radwaste Materials in Kori Unit 1 Based on the Radioactivity Data of Steam Generator Replacement in Korea”, Master’s Degree, Hanyang University
[5] K.I. Jung, N.G. Jeong, Y.P. Moon, M.S. Jeong, and J.B. Park, “Prediction of Radionuclide Inventory for the Low-and Intermediate-Level Radioactive Waste Disposal Facility by the Radioactive Waste Classification”, JNFCWT, 14(1), 63-78 (2016)
[6] Korea Foundation of nuclear safety, C.R. Kim, “Final report on technology development for nuclear power plant decommissioning waste management and radiation environment impact verification and evaluation regulatory elements”, R&D, 1305009-0517-SB120 (2018)
[7] J.S. Song, Y.G. Kim, S.H. Lee, “A Pre-study on the estimation of NPP Decommissioning Radioactive Waste and Disposal costs for Applying New Classification Criteria (2015)
[8] K.I. Jung, J.H. Kim, M.J. Kwon, M.S. Jeong, S.W. Hong, J.B. Park, “Comprehensive Development Plans for the Low-and Intermediate-Level Radioactive Waste Disposal Facility in Korea and Preliminary Safety Assessment”, Technical Paper, JNFCWT, 14(4), 385-410