A Study on the Regulation Improvement Through the Analysis of Domestic and Foreign Categorization for Radioactive Waste and Decommissioning Cost

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1. Introduction

In the Republic of Korea, there are approximately 20 nuclear power plant including Kori Unit 1, which was decided to permanently shut down. The expected shutdown year of each nuclear power plants is shown in Table 1 [1]. In 2015, the regulation on preparation of (preliminary) decommissioning plan is established by Nuclear Safety and Security Commission [2]. Decommissioning plan should be submitted by 2018. Decommissioning plan includes the following contents [2].; project management (organization and labor force, cost, securing financial resources), status of site and environment, strategy and method of decommissioning, safety assessment, radiation protection, decontamination and decommissioning activity, management of radioactive waste, environmental effects evaluation, etc. So, we need to establish the detailed regulation on decommissioning cost.

In case of Europe, the report on exemption criteria of decommissioning material of each countries and disposal method for radioactive waste was published [3,4]. Also, type of decommissioning cost is classified into 4 groups according to the report of OECD/NEA [5].; Activity-dependent costs, Period-dependent costs, Collateral and special item costs, Contingency costs. The cost driver of decommissioning cost was analyzed by OECD/NEA [5]. Therefore, we aim to establish a foundation for decommissioning of nuclear related facility through the analysis on the disposal method depending on classification criteria of radioactive waste and the analysis on the type and cost driver of decommissioning cost in foreign countries.

Table I: Operation status and expected shutdown year of NPP in the Rep. of Korea (NPP : Nuclear Power Plant)

NPP	Type	Termination	NPP	Type	Termination
Kori 1	PWR	2017	Hanbit 1	PWR	2026
Kori 2		2023	Hanbit 2		2027
Kori 3		2025	Hanbit 3		2035
Kori 4		2026	Hanbit 4		2036
Shin-Kori 1	PWR	2051	Hanbit 5		2042
Shin-Kori 2		2052	Hanbit 6		2042
Wolsong 1	PHWR	2022	Hanul 1	PWR	2028
Wolsong 2		2027	Hanul 2		2029
Wolsong 3		2028	Hanul 3		2038
Wolsong 4		2029	Hanul 4		2039
Shin-Wolsong 1	PWR	2052	Hanul 5		2044
			Hanul 6		2045

2. Foreign categorization and disposal method of radioactive waste [3,4]

In case of Europe, decommissioning materials include only the materials arising from decontamination and dismantling of nuclear facilities. These waste were managed in the following methods.; recycling in the nuclear field, self–disposal (if it is possible to exempted from regulation), management as radioactive waste.

2.1 Belgium

Radioactive waste in Belgium are divided largely into three categories based on the half-life period($T_{1/2}$) and the emitting radiation.

- Category A : Low and medium activity waste containing beta-gamma radionuclides of $T_{1/2} \leq 30$ y and only traces of alpha, beta, gamma radionuclides with $T_{1/2} > 30$ y.
- Category B : Waste containing radionuclides (alpha emitters) with $T_{1/2} > 30$ y
- Category C : Alpha, beta, gamma waste containing large amounts of radionuclides with $T_{1/2} > 30$ y

Also, radioactive waste other than waste that meets the criteria for clearance shown in Table 2 is disposed as follows.

- Category A : Formerly sea dumping, New option under study
- Category B and C : Deep geological formation

Table II: Criteria for clearance of decommissioning materials (Belgium)

Radioactivity limitation	Material
- Specific activity : 1 Bq/g for total activity averaged over 1,000 kg - Surface contamination : 0.1 Bq /m^2	Concrete buildings; Steel tanks (reused)

2.2 France

Radioactive waste in France are divided largely into two categories based on the existence of radionuclides according to half-life period($T_{1/2}$) and the average radioactivity per package.

- Category 1(Type A) : Containing mainly radionuclides $T_{1/2} < 30$ y and very few radionuclides with much longer $T_{1/2}$. Notably an average specific activity of alpha emitters for all

the packages in the repository, calculated at the end of the institutional period not to exceed 370 Bq/g (10 nCi/g) and a max. Alpha-specific activity per package less than 3,700 Bq/g (100 nCi/g).

- Category 2(Type B) : Containing significant amounts of radionuclides $T_{1/2}$ > 30 y, except vitrified solutions of fission products from spent fuel reprocessing.
- Category 2(Type C) : Resulting from vitrification of fission products(f.p) products from spent fuel reprocessing.

Also, radioactive waste other than waste that meets the criteria for clearance shown in Table 3 is disposed as follows.

- Category 1(Type A) : near surface disposal
- Category 2(Type B, C) : deep geological formation on continent

Table III: Criteria for clearance of decommissioning materials (France)

Radioactivity limitation	Material
- Specific activity(β -ɣ) : 0.5 Bq/g - Surface contamination(β -ɣ) : 2.5 Bq /m^2	Carbon steel parts from GCR Primary circuit

3. Type and cost driver of decommissioning cost [5]

Type of decommissioning cost that proposed by OECD/NEA are largely divided into 4 groups.; Activity-dependent costs, period-dependent costs, collateral and special item costs, contingency costs. Activity-dependent costs are related to performing decommissioning activities. In case of France and Slovakia, costs associated with radiological inventory are categorized as activity-dependent costs. Period-dependent costs include the following contents.; project management, surveillance, maintenance, operating costs of equipment need to perform decommissioning, etc. In case of Italy, collateral costs are estimated based on benchmark performing by contractors that conduct study on decommissioning plan. Finally, contingency costs are defined as unpredictable cost elements in project's scope. The cost drivers of decommissioning cost are largely divided into four groups.; Basic assumptions and inclusions in the boundaries of the estimate, Sources for unit cost for various activities, Assumptions for waste management/comprising, Technical assumptions for decommissioning/comprising. Details of each groups are presented in Table 4.

Table IV: Details according to the type of cost driver

Basic assumptions and inclusions in the boundaries of the estimate
- Year of estimate monetary units - Start point for decommissioning and definition of physical boundaries of the project - End-point criteria and conditions for the facility and site - Transition from operation to decommissioning, including characterisation and inventory - Ongoing operations not specific to active decommissioning
Sources for unit cost for various activities
- Source of employee salary and craft labour rates used in the estimate - Source of material and equipment costs for conventional demolition of clean equipment and structures - Source of material and equipment costs for the monitoring, decontamination and dismantling of contaminated materials and buildings
Assumptions for waste management, comprising
- Disposition of legacy wastes (including melting of contaminated metals and recycling options) - Waste canister options (including capacity, design life, and limitations on their use) - Waste storage and disposal facilities - Waste transportation options, including weight or radioactivity limits on containers and casks - High-level waste and spent nuclear fuel disposition
Technical assumptions for decommissioning, comprising
- Major component disposition - Scrap and salvage disposition - Construction of new facilities or modification of existing facilities to facilitate decommissioning - Structure disposition - Infrastructure disposition - Strategies for procurement and overall project management - Yield ratios associated with intervention techniques (i.e. choice of technologies for remote handling)

4. Categorization of radioactive waste and decommissioning cost in the Rep. of Korea [6]

Categorization of radioactive waste in the Republic of Korea is shown in Fig 1. Disposal method for each radioactive waste is as follows.

- Very low level waste can be disposed of by nearsurface disposal or deep disposal.
- Low level waste can't be disposed of by landfill disposal.
- Intermediate level waste can't be disposed of by surface disposal or landfill disposal.
- High level waste can't be disposed of by nearsurface disposal.

But, there is no disposal site for very low level waste in the Republic of Korea. Also, except the management cost of intermediate and low level waste, there is rough regulation on the contents related to decommissioning cost but there is no detailed regulation.

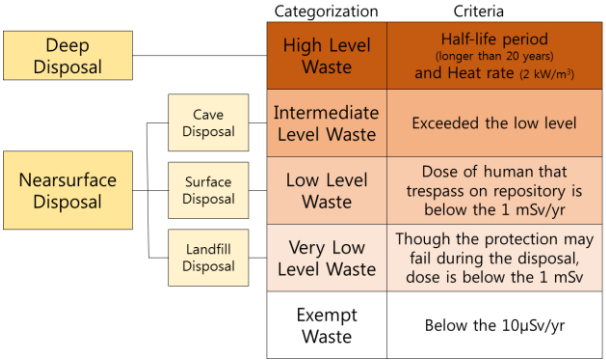

Fig. 1. Categorization of radioactive waste in the Rep. of Korea

5. Conclusions

In the Republic of Korea, disposal method according to the categorization of radioactive waste is established by regulation and there is disposal site for intermediate and low-level waste. But, there is no disposal site for very low level waste. If the nuclear related facility is decommissioned in this situation, we expected that very low level waste which is produced during decommissioning will be disposed in repository for intermediate and low-level waste. So, we expected that unnecessary decommissioning cost increase.

There is no detailed regulation on the contents related to decommissioning cost in the Republic of Korea. But, we identified that there are various factors related to decommissioning costs through the analysis of literature survey. The domestic regulation improvement that comes from analysis of type and cost driver of decommissioning cost is as follows.

- Because there is no categorization of decommissioning cost and the collateral and special item costs is similar to contingency costs, type of decommissioning cost will be divided into 3 groups.; Activity-dependent costs, period-dependent costs, contingency costs.
- Whether decommissioning cost includes the disposal cost of radioactive waste arising from operation
- Decision on the ratio of contingency cost (15% of total(Belgium), 25% for preliminary estimates (Slovakia), 20% for detailed estimates (Slovakia))

Therefore, if we suitably change the items related to decommissioning cost and it is applied to decommissioning of nuclear related facilities, we will expect that it reduces the confusion of decommissioning manager and estimate more exactly the decommissioning cost.

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