Correlations Between Safety Assessment and WDFs in NPP Decommissioning

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1. Introduction

Decommissioning is the last phase of the nuclear power plant (NPP) life cycle followed by the site release. OECD/NEA defines the decommissioning as all of the administrative and technical actions associated with early planning for cessation of operations through termination of all licenses and release of the site from nuclear regulatory control [1]. Korea Hydro and Nuclear Power (KHNP) made a decision for permanent shutdown of Kori-1 on June 18th, 2015, which, finally, has been shut down since June 19th, 2017.

To date, Korea has no decommissioning experiences on a commercial nuclear reactor but on a research reactor. Accordingly, KHNP has begun to develop necessary decommissioning technologies which helps reduce uncertainties and avoid risky events with regard to hazards and safety. Hence, this paper mainly deals with correlations between safety assessment and Work Difficult Factors (WDFs) in decommissioning. In addition, we try to suggest systematic application of those correlations for the effective decommissioning of Kori-1 NPP.

2. Methodologies & Results

Safety assessment is closely related to work difficulties of decommissioning workers, which has an immediate impact on decommissioning costs. Due to the correlation between safety assessment and work difficulties, as a matter of fact, OMEGA, one of the decommissioning cost estimation programs, has the function to consider occupational dose in calculating decommissioning costs. It has become essential that safety assessment is a key process to estimating decommissioning costs.

2.1 Safety Assessment for Decommissioning

Safety assessment considers consequences and frequencies of the failure and events based on hazard analysis. Due to the characteristics such as activation and contamination of structure, system and components (SSCs) in decommissioned NPP, both industrial (non-radiological) and radiological hazards should be taken into account.

2.1.1 Industrial Hazards. Non-radiological and industrial hazards are obviously identified taken place or not. Thus, they are analyzed into the complex results by consequence (severity) exemplified in Table 1 and frequency (probability, likelihood) shown in Table 2. Fig. 1 illustrates the complex results of industrial hazards as a matrix of consequence and frequency [2]. Main industrial hazards are represented as fire, explosion, flooding, toxic, electrical, physical, human errors, etc.

Table 1. Consequence of industrial hazards

Level	Consequence (Severity)
1	No loss (No effect)
2	Lost day work (1 day ~ 1 week)
3	Injury (1 week ~ 3 months)
4	Disabilities (3 months ~ 1 year)
5	Fatalities (More than 1 year, death)

Table 2. Frequency of industrial hazards

Level	Frequency (Probability/Likelihood)
1	Rare (Less than 10 %)
2	Unlikely (10 % ~ 25 %)
3	Possible (25 % ~ 50 %)
4	Likely (50 % ~ 75 %)
5	Almost certain (More than 75 %)

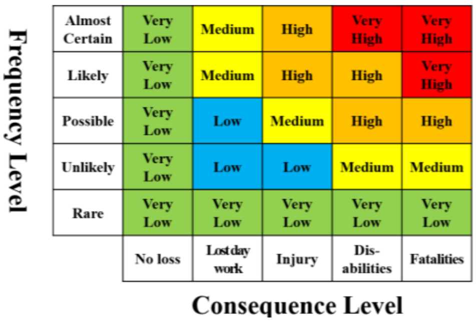

Fig. 1. Risk matrix of industrial hazards.

2.1.2 Radiological Hazards. Since decommissioning workers often conduct in radiological environments, they could be frequently exposed to the environment of radiological hazards [3].

Radiological hazards also can be classified by their consequences. Table 3 shows the categorization of radiological hazards by consequence and frequency.

Table 3. Categorization of radiological hazards

Consequence / Frequency	Low	Moderate	High
$< 10^{-6}$/yr	Class 4	Class 4	Class 3
$10^{-6} \sim 10^{-4}$/yr	Class 4	Class 3	Class 2
$10^{-4} \sim 10^{-2}$/yr	Class 3	Class 2	Class 1
$10^{-2} \sim 10^{-1}$/yr	Class 3	Class 1	Class 1

2.2 Work Difficulty Factors

WDFs are weighted values of durations and costs for decommissioning activities. Table 4 demonstrates the representative WDFs such as accessibility, ALARA (radiation condition), respiratory protection measures, personal protection clothing etc. [4]. WDFs could be additionally defined if another factor is needed to more accurately consider the work environment.

Table 4. Composition of Work Difficulty Factors

WDF	Description
Accessibility	Structural complexity in workspace
ALARA	Radiation condition and training
Respiratory	Respirator protection equipment
Prot. Cloth	Wearing radiation protective clothes

2.3 Application of Safety Assessment to WDFs

Results of safety assessments are able to a part of WDFs according to their characteristics of the corresponding hazards. For instance, physical hazard could change the accessibility factor; exposure dose rate alter the ALARA factor, the measures of radiation protection turn into respiratory protection and personal protection clothing factors. Especially, radiological hazard is dependent on anticipated occupational dose. In some cases, the total WDF value would be maximized to 356% as demonstrated in Table 5 [3].

Table 5. Total WDF values by dose rate phases

Dose rate phase	Total WDF values			
	Case 1	Case 2	Case 3	Case 4
Phase 1	1	1.32	1	1
Phase 2	1.2	1.8	1.55	1.21
Phase 3	1.4	1.92	1.67	2.2
Phase 4	1.6	2.28	2.02	2.57
Phase 5	2.4	2.47	2.66	3.56

3. Conclusions

Safety assessment is one of the most important processes for the safety of on-site occupational workers and nearby residents. Therefore, WDFs reflecting the results of safety assessment will highly influence decommissioning activity costs. However, accurate safety assessment prevent more drastic increase of costs occurred by severe accidents. From this study, we find that there are deep correlations between safety assessment and decommissioning activities, which eventually leads to rational, economical and safe decommissioning.

REFERENCES

[1] Nuclear Energy Agency, Improving Nuclear Regulation, NEA No. 6275, OECD (2009).
[2] K.-S. Jeong; B.-S. Choi; J.-K. Moon; D.-J. Hyun; J.-H. Lee; G.-H. Kim; H.-S. Hwang; S.-Y. Jeong and J.-J. Lee, Risk reduction approach to decommissioning hazards of nuclear facilities, Annals of Nuclear Energy, 63, 382-386 (2014).
[3] IAEA, Safety Assessment for Decommissioning, Safety Reports Series No. 77, IAEA (2013).
[4] Thomas S. L., etc., Guidelines for Producing Commercial Nuclear Power Plant Decommissioning Cost Estimates, AIF/NESP-036, Volume 1 (1986).