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Methodology to Link the Results of Radiological Characterizations of Decommissioning Nuclear Power Plants

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Kori Unit 1, the first commercial nuclear power plant (NPP) in Korea, was permanently shut down in 2017 and was scheduled for decommissioning. Various programs must be planned early in the decommissioning process to safely decommission NPPs. Radiological characterization is a key program in decommissioning and should be a high priority. Radiological characterization involves determining the decommissioning technology to be applied to a nuclear facility by identifying the radiation sources and radioactive contaminants present within the facility and assessing the extent and nature of the radioactive contaminants to be removed from the facility. This study introduces the regulatory requirements, procedures, and implementation methods for radiological characterization and proposes a methodology to link the results of radiological characterizations for each stage. To link radiological characteristics, this study proposes to conduct radiological characterization in the decommissioning phase to verify the results of radiological characterization in the transitional phase of decommissioning NPPs. This enables significantly reducing the scope and content of radiological characterization that must be performed in the decommissioning phase and maintaining the connection with the previous phase.

Keywords: Nuclear power plants, Decommissioning, Radiological characterization, Final decommissioning plans

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1. Introduction

Kori Unit 1, the first commercial nuclear power plant (NPP) to be decommissioned in Korea, was permanently shut down in June 2017. Korea Hydro & Nuclear Power (KHNP), the decommissioning licensee, prepared a final decommissioning plan (FDP) to proceed with the decommissioning of Kori Unit 1 and applied for decommissioning approval from the Nuclear Safety and Security Commission (NSSC), the regulatory body, in May 2021 [1]. This FDP contains various technical contents related to the decommissioning of NPPs; among them, the most important assessment is radiological characterization.

Radiological characterization involves investigating the radiological properties (radiation dose rates, radionuclide concentration, distribution, and contamination levels) for various purposes during the NPP phases of design and construction, operation, transition, decommissioning and demolition, and site remediation and reuse. It also plays a key role in determining the technologies to be applied for the decommissioning-demolition of high-radiation areas and Systems, Structures, and Components (SSCs) [2, 3]. The connection of radiological characterizations between each phase (transition, decommissioning, and demolition phases) is critical for the safe decommissioning of an NPP. Each phase, which uses radiological characterization for decommissioning the NPPs, is shown in Fig. 1 [4].

Radiological characterization is one of the key steps for decommissioning a nuclear facility and should be conducted as a top priority. Radiological characterization plays a major role in determining the decommissioning technology to be applied to a facility by accurately identifying the source of radiation and radioactive contamination in the facility and evaluating the levels and characteristics of radioactive contamination to be removed from the facility. Therefore, radiological information on SSCs and sites should be identified and recorded during the construction and operation of NPPs, and radiological characterization should be systematically performed during the transitional period after a permanent shutdown. Additionally, radiological characterization should be tailored to the concerns and characteristics of the cutting and demolition, waste management, and site remediation processes. Radiological characterization is an integral element of the decommissioning process that determines the safety and economic viability of decommissioning NPP, including decision-making, authorization, and selection of decommissioning technologies, as well as post-decommissioning activities from cutting and demolition to site reuse [5]. Radiological characterization in the decommissioning and demolition phases affects various aspects, including the scope and type of decommissioning work, decommissioning safety assessment, and protection of workers, the public, and the environment, and has a significant impact on the management of non-radioactive materials and radioactive waste generated by decommissioning. Therefore, radiological characterization is not limited to the decommissioning of nuclear facilities but also has high importance in the planning, review, optimization, implementation, and closure of long-term decommissioning projects [6].

In the decommissioning and demolition phases, radiological characterization is not an independent program of the decommissioning-demolition phase but an extension of radiological characterization in the previous phase, the transition phase, and serves as an important input for radiological characterization in the next phase, the site remediation and reuse phases [6]. These radiological characterizations serve as key tools for maximizing the safety and efficiency of decommissioning and minimizing environmental impacts. Additionally, radiological characterization has a significant impact on the planning and implementation of subsequent phases and is an essential element in ensuring connection and consistency throughout the entire process. Therefore, for an NPP to be properly dismantled, it is necessary to find a method for linking radiological characterizations for each step and preventing the results of the radiological characterization from becoming useless. In addition, it is necessary to comply with the disposition acceptance

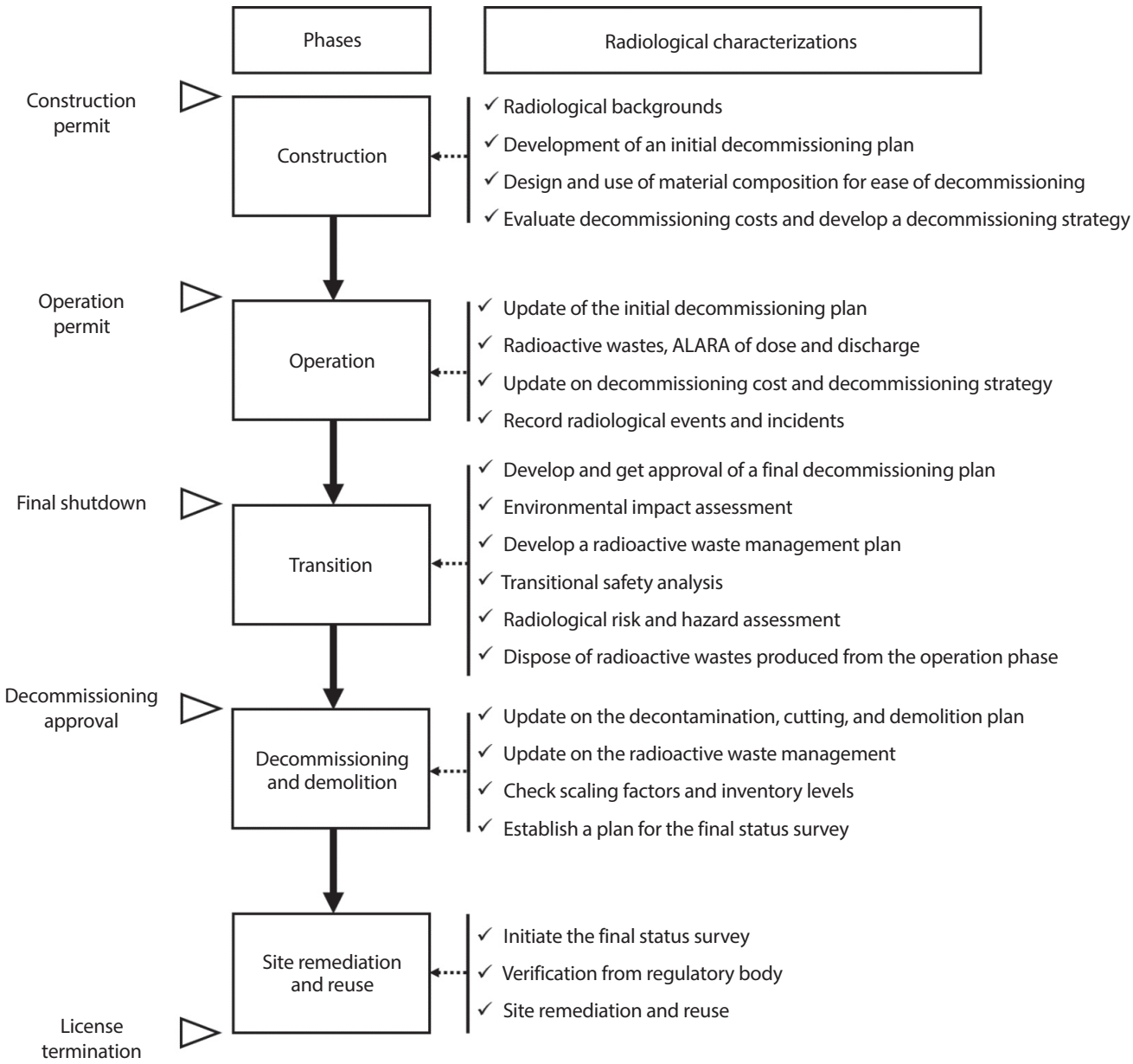

Fig. 1. Radiological characterizations in phases of nuclear power plants.

criteria for decommissioning waste and to prevent nonconformity with the final disposal. Therefore, the purpose of this study is to propose a methodology to link the results of radiological characterizations in the NPP phases to be decommissioned in Korea.

2. Materials and Methods

To propose a methodology to link the results of radiological characterizations in the phases of decommissioning NPPs, this study analyzed the regulatory requirements of

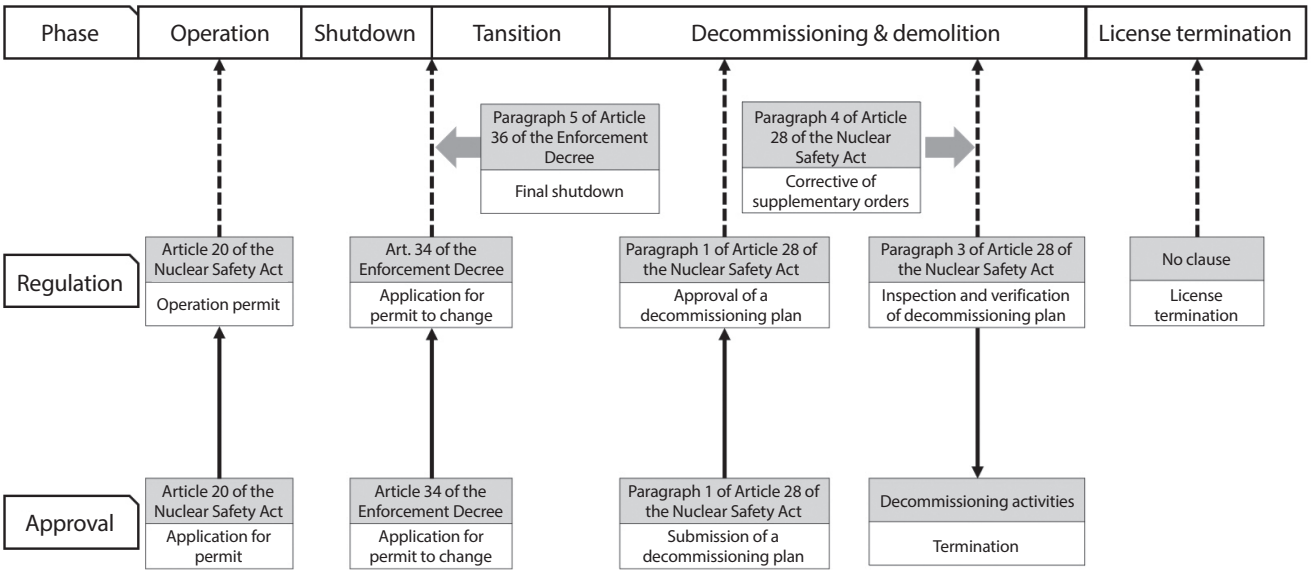

Fig. 2. Regulatory framework for operating and decommissioning nuclear facilities.

Table 1. Objectives and scope of radiological characterization

Objectives	Extent	Scope
Support development of decommissioning strategy (application of dismantling steps)	Facility (all systems, buildings, and areas)	• Operational history • Facility construction and materials composition and volume • Activation calculations, dose rates • Total radioactivity distribution • Key radiological and non-radiological contaminants
Risk assessment	Main activated and contaminated areas	• Past events • Inventory within systems, tanks, etc. • Nature of inventory fixed or mobile
Preparation for post-operation clean-out and decontamination	Primary circuit (without damage), systems, tanks, effluent treatment systems, and waste packages	• Key radiological and non-radiological contaminants • Dose rates • Total radioactivity distribution • Contamination depth
Estimation of waste volumes per category	Systems, building structures, radioactive and hazardous waste	• Operational history • Facility construction and materials composition and volume • Activation calculations • Total radioactivity distribution • Key radiological and non-radiological contaminants • Applicability of volume reduction techniques
Worker protection, work permissions	Buildings, systems and components, waste, residues, sludges dependent on nature of work	• Previous radiation surveys • Dose rates • Alpha-contamination levels • Presence of pathogens and chemical toxins

Objectives	Extent	Scope
Categorization and sentencing of waste	Waste arisings	• Previous radiation surveys and other provenance • Determination of scaling factors • Detailed surveillance of waste supported by scaling factors and consideration of uncertainty • Chemical characterization and surveillance
Clearance of the buildings	Surface (and subsurface) of the buildings and site, buried systems and components	• Previous radiation surveys and other provenance • Determination of scaling factors • Detailed characterization supported by scaling factors, as available and appropriate • Surface contamination, activation levels, and activity concentrations • Consideration of contamination penetration and mobility behavior and potential for contamination in inaccessible areas

Table 2. Scope of radiological characterization in the initial decommissioning plan for Kori Unit 1

Classification		Scope
Radiological characterization	Facilities assessment	• Calculations over time after permanent shutdown, based on the radionuclides and amounts present in the plant at the time of permanent shutdown • Gamma radiation level measurement • Beta and gamma radiation survey • Alpha radiation survey • Smear survey • Water and sludge sampling • Surface and subsurface soil sampling • Sample pipes and appliances • Concrete sampling • Metals sampling • Epoxy and paint sampling, etc.
	Historical assessment	• Historical site assessment • Contamination scoping survey • Detailed characterization survey • Remedial action support survey • Final status survey

radiological characterization in the NSSC notification and FDP review guidelines provided by the Korea Institute of Nuclear Safety (KINS), a technical expert organization for nuclear safety regulation in Korea [7, 8]. Furthermore, this study analyzed the role of radiological characterization and the necessity of each phase of NPP to explain the link between radiological characterizations. Fig. 2 shows the regulatory system for the operation and dismantling of nuclear facilities described in the Korean Nuclear Safety Act and the Enforcement Decree of the Act [9, 10]. The requirements, procedures, and methods for radiological characterization were analyzed by referring to OECD/NEA reports and the Nuclear Safety Technology Analysis Report (N-STAR) of the Korea Foundation of Nuclear Safety [2, 6, 11]. These reports suggest the following radiological characterization procedures: operational history investigation,

neutron irradiation and corrosion product inventory calculations, non-destructive radiation and radioactivity measurements, sampling, destructive radiation, and radioactivity measurements [11]. Table 1 lists the purpose and scope of radiological characterization presented in the OECD/NEA report [11].

In addition, this study reviews the initial decommissioning plans (IDP) submitted by decommissioning licensees to the regulatory body to decommission NPPs. The IDP for Kori Unit 1 contains a radiological characterization, as listed in Table 2 [12]. It also identifies the scope and type of decommissioning work and describes the content for conducting dismantling safety evaluations, including protecting workers, the public, and the environment [12].

This study reviewed the IDPs of decommissioning licensees, N-STAR, and OECD/NEA reports and suggested a methodology for linking radiological characterizations [13]. Furthermore, this study makes it possible to determine the appropriateness of the radiological characterization process by providing Korean regulatory requirements, procedures, methods, and linkage measures for radiological characterization. In particular, considering the radiological characterization of the decommissioning and demolition phases, methods to link radiological characterization in the transitional phase prevent the results of radiological characterization in the transitional phase from being useless, thereby minimizing radiation exposure for workers and ensuring radiation safety.

3. Results and Discussions

3.1 Korean Regulatory Requirements for Radiological Characterization

The regulatory system for decommissioning nuclear facilities in Korea is based on Article 28, Paragraph 1 of the Nuclear Safety Act and Article 27, Paragraph 1 of the Enforcement Rules accordingly [9, 10, 14]. According to the provisions of this Act, if a decommissioning licensee intends to decommission a nuclear facility, they must first complete and submit a decommissioning plan approval application to the NSSC. This application describes in detail the decommissioning plan for the final reactor facilities and the quality assurance plan for decommissioning. Then, the NSSC reviews the submitted decommissioning plan, evaluates its safety, and determines whether it should be approved. In addition, before the decommissioning of a nuclear facility is completed, the regulatory body must periodically check and inspect the decommissioning process. Radiological characterization is essential to establish a thorough radiation management system and to ensure safety from the risk of radiation exposure to the surrounding environment and the public. Fig. 2 shows the regulatory system related to the operation and decommissioning of nuclear facilities [9, 15].

Radiological characterization during the decommissioning and demolition phases identified the type, amount, and distribution of radioactive materials present in the decommissioning NPP and site, which were important for inclusion in the IDP and FDP. According to the regulations on the preparation of NSSC Notice No. 2021-10 on the decommissioning plan for nuclear facilities, the IDP outlines the methods and procedures for radiological characterization during the construction and operation of NPPs and presents the results of the preliminary source term evaluation of the NPP [7]. This regulation is required in the early phase of decommissioning to identify the radioactivity of radioactive materials in the structure and to be utilized in future decommissioning programs. The notice also requires the FDP to describe the methods and procedures of radiological characterization more systematically. In particular, the regulation requires identifying the type, amount of radioactivity, distribution, and extent of radioactive substances present not only in the SSCs of decommissioning NPPs but also in the soil, subsurface soil, surface water, and groundwater of the NPP site using appropriate assumptions and methodologies [6, 7]. The regulatory requirements for the radiological

Table 3. Korean regulatory requirements for radiological characterization during decommissioning nuclear power plants

Classification		Contents
Laws and regulations		Nuclear Safety and Security Commission No. 2021-10 Regulations on Preparation of Decommissioning Plans for Nuclear Power Facilities
Category		3. Site and Environmental Status
Subcategory		3) Radiological Characteristics
Requirements	IDP	• Outline the methods and procedures for investigating the type, amount, and distribution of radioactive materials present at the facility and site to be decommissioned. • Present the results of the radiation source assessment for the nuclear facilities and site to be decommissioned and outline the basis, methods, and assumptions used in the assessment.
	FDP	• Describe methods and procedures for investigating the type, amount, and distribution of radioactive materials present in the facilities and sites to be decommissioned. • Present the types, amounts, distribution, and extent of radioactive contamination of radioactive materials in structures, systems, and equipment to be dismantled and describe the basis, methods, and assumptions used. • Present the type, amount of radioactivity, distribution, and extent of radioactive contamination of the soil and underground soil of the facilities and sites subject to dismantling and describe the basis, methods, and assumptions used herein. • Present the surface water of the facilities and sites subject to dismantling, the type of radioactive material present in groundwater, the amount of radioactivity, distribution, and the extent of radioactive contamination, and describe the basis, methods, and assumptions used herein.

Table 4. Verification of methodology for radiological characterization in the final decommissioning plan review guidelines

Classification	Contents
Historical evaluation of the decommissioning site and facilities	• Establishment of a survey plan • Identification of contamination and levels
Rough survey of contamination ranges	• Establishment of a rough survey plan based on history evaluation • Direct and indirect measurements and analysis of sites and facilities subject to decommissioning
Detailed radiological characterization	• Establishment of a survey plan for detailed radiological characterization based on history evaluation and rough survey • Calculation method of radiation source term (inventory) using various numerical analysis codes • Direct measurement of radiation and radioactivity using radiometer, etc., for facilities and sites to be decommissioned • Indirect measurement and radioactivity analysis of radionuclides and concentrations by sampling methods for facilities and sites to be decommissioned • Confirmation of the appropriateness of detailed radiological characterization through comparison and analysis of historical evaluation and rough survey results • Trend analysis of radiological characteristics and calculation of scaling factors, etc.

Table 5. Application of radiological characterization

Division	Contents
Decommissioning strategy and timeline	• Establishing a decommissioning strategy and reflecting it in the decommissioning schedule
Radiation protection	• Establishment of dismantling radiation protection plan, including dismantling safety assessment for workers and the general public • Establishment of a high radiation work plan based on the results of the survey, such as dose rate, airborne concentration, and residual radioactivity
Decommissioning activities	• Plan to reflect on decommissioning activities (decontamination and demolition) by characteristics such as radiation and radioactivity levels and contamination scope
Radioactive waste	• Plan to be utilized in the evaluation and prediction of radioactive waste generation • Plan to be utilized in disposal plan, including application of decommissioning waste reduction method and application of scaling factors

characterization of decommissioning NPPs, as required by the Korean Nuclear Safety Act, are listed in Table 3 [7].

Radiological characterization plays a key role in the decommissioning of nuclear facilities. The regulatory requirements for radiological characterization are detailed in the FDP review guidelines provided by KINS [8]. This review guideline provides the verification requirements for the methodology of radiological characterization to investigate the types, amount of radioactivity, and distribution of radioactive materials present at sites and facilities to be decommissioned, as listed in Table 4 [8]. In addition, based on the results of the radiological characterization conducted by the decommissioning licensee, the KINS suggests that the linked scopes, such as the decommissioning strategy and schedule, decommissioning safety assessment, decommissioning radiation protection plan, decommissioning waste management, and environmental impact assessment, should be described, as listed in Table 5 [8]. The FDP review guidelines suggest that the regulatory body should verify that radiological characterization in the transitional phase has been adequately conducted and use the results to determine whether to authorize decommissioning. Therefore, the results of the radiological characterization in the transitional phase must be linked to the radiological characterization in the decommissioning and demolition phases to ensure that the established decommissioning plan, radiation protection plan, and waste management plan are conducted continuously.

3.2 Procedures and Methods of Radiological Characterization

To perform radiological characterization, the procedures should be described in detail when establishing a plan for radiological characterization, and specific implementation methods for each procedure should be presented. The main procedures for radiological characterization include operational history investigations, neutron irradiation and corrosion product inventory calculations, non-destructive radiation and radioactivity measurements, sampling, and destructive radiation and radioactivity measurements [11]. The FDP review guidelines require that these procedures be performed during radiological characterization, focusing on a historical assessment of the decommissioning site and facilities, a rough investigation of contamination ranges, and detailed radiological characterization. According to the review guidelines, the historical assessment of the site and facilities constitutes an operational history investigation

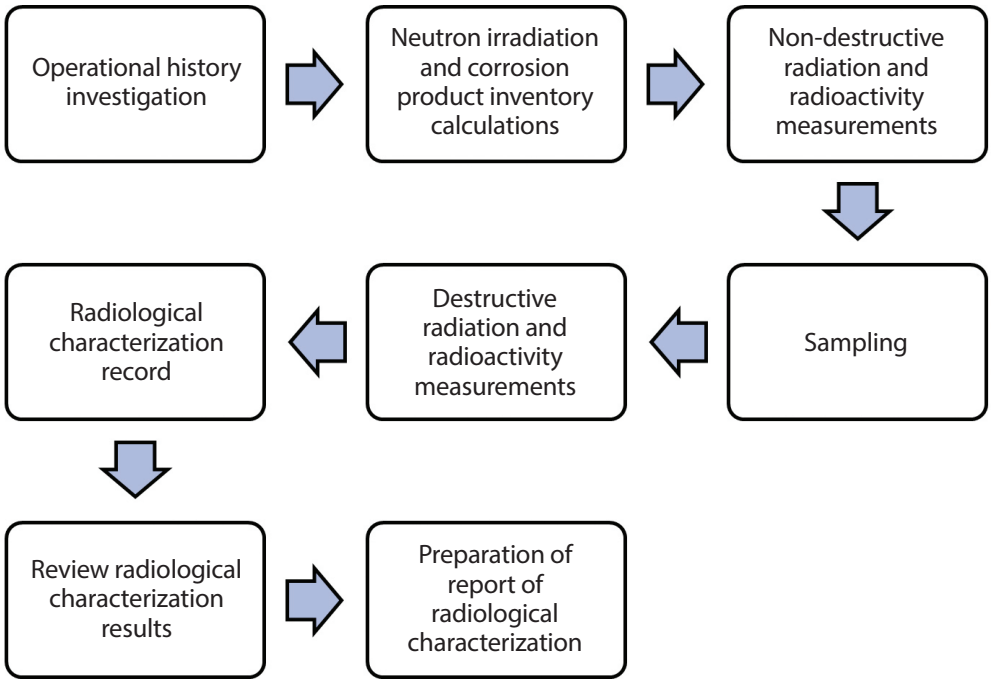

Fig. 3. Key procedures for radiological characterization in the transition phase.

during radiological characterization. The direct and indirect measurements and analyses required by a rough investigation of contamination ranges constitute non-destructive and destructive radiation and radioactivity measurements and sampling during radiological characterization. In addition, detailed radiological characterization included calculating the activation inventory, recording the radiological characterization, verifying the appropriateness of the results, and preparing reports. Fig. 3 shows the main procedures used for radiological characterization in the transition phase [6, 8, 11].

Radiological characterization proceeds by collecting the operational history information of the facility to be decommissioned and evaluated appropriately. By organizing the operational history information collected during this process and the characteristics of radioactive contamination, it was possible to assess the extent of contamination in each area accurately. The results of these assessments play an important role in determining the amount and quality of information required to perform future radiological characterizations. The results of an operational history investigation can be an important reference for conducting future radiological characterizations [6].

Neutron irradiation and corrosion product inventory calculations are topics for the theoretical calculation and evaluation of the activation inventory (or source term) of neutron irradiation during NPP operation. This allows the decommissioning licensee to calculate the activation nuclides for each area around the reactor core and evaluate the radionuclide concentration and levels in each area to systematically categorize radioactive waste. The neutron flux and energy spectra of the core and the activation source terms can be calculated using computer codes. Representative codes include the Monte Carlo N-Particle (MCNP)/FISPACT and the Particle and Heavy Ion Transport code System (PHITS).

Direct or in-situ methods are utilized for non-destructive radiation and radioactivity measurements. These

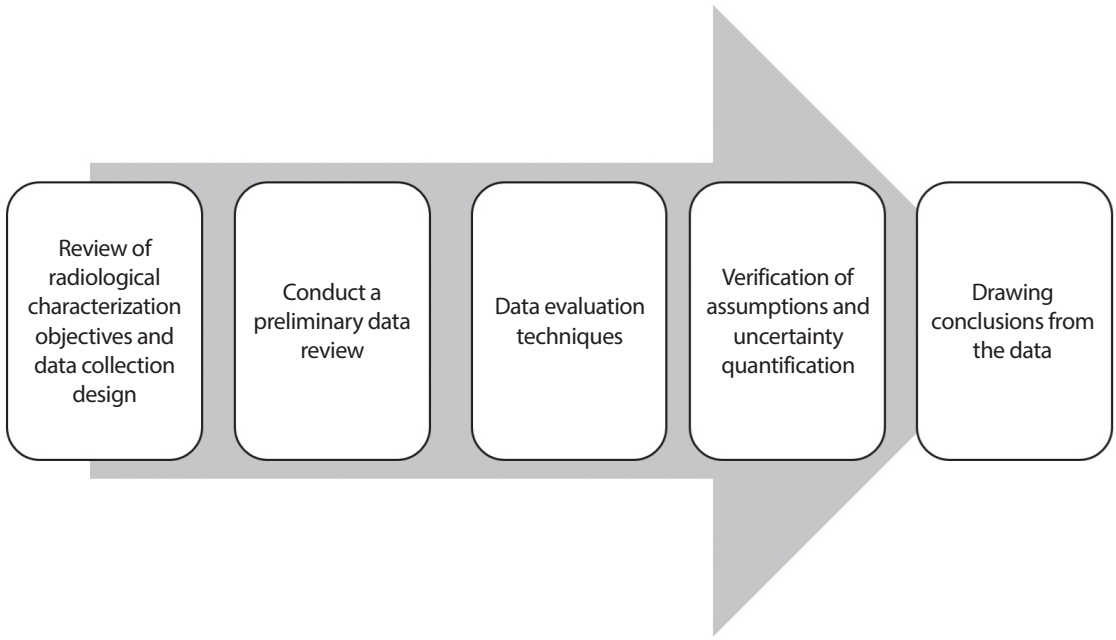

Fig. 4. Steps to assess data quality.

methods are primarily used to measure the radiation and radioactivity of materials or wastes using radiation- and radioactivity-measuring instruments in the field rather than in the laboratory. Non-destructive radiation and radioactivity measurement instruments include gamma and alpha cameras (capable of mapping radioactivity intensity), alpha-beta-gamma radioactivity measuring instruments (capable of measuring total radioactivity by location), and nuclide-specific radiation detectors [6].

Sampling, destructive radiation, and radioactivity measurement methods involve destructive sampling of the substance to be measured using various types of sampling equipment and the analysis of the radiation and radioactivity of the sample at a separate location. This method has the disadvantage of being expensive and time-consuming compared to non-destructive measurement methods; however, it must be used for important decision-making in the decommissioning process because it can check the type and amount of radiation of the target sample. In addition, destructive radiation and radioactivity measurements typically involve the dissolution of a sample using strong acids, oxidizing agents, or high-temperature treatments, which often result in the presence of contaminants in a liquid state. Currently, chemical separation methods are used to purify and analyze the required elements or components. If an alpha spectrometer is used for radiological characterization after sample preparation, such as by evaporation or electrodeposition onto an iron disk, detection and analysis of radioactivity in standard fixed forms with a known counting efficiency are conducted. Therefore, it is important to improve the reliability of radiological characterization by utilizing destructive measurement methods as supplements and to minimize destructive sampling, radiation, and radioactive analysis.

When performing radiological characterization, significant amounts of data and records are generated, which must be maintained for many years. These records allow the radiological characterization results to be tracked to a specific sample or measurement location to confirm the accuracy of the results. Procedures and systems must be prepared for data management, including the collection, management, storage, and access to radiological characterization data and records. In particular, it is important to establish a

unique coding system that includes all relevant structures, instruments, measurement locations, systems, waste packages, sampling points, and analyses to maintain the traceability of radiological characterization data and records. In addition, organizations that collect and evaluate radiological characterization data should consider the quality of the data and results. Radiological characterization results should meet clearly defined requirements, uses, purposes, and program requirements. To achieve this, technical, administrative, and human factors affecting the quality of radiological characterization results must be controlled. In addition, scientific and statistical evaluations were performed to ensure that the type, quality, and quantity of radiological characterization data met the radiological characterization objectives and were appropriate for supporting relevant decision-making processes. Fig. 4 shows the data quality assessment phase [6].

The final step in radiological characterization is the preparation of a report. Various activities are performed through radiological characterization, and numerous documents, such as plans, records, and evaluation reports, are prepared based on this. Therefore, it is important to organize the completed work, the results obtained, their meaning, and their relationship with the goal of radiological characterization. In particular, it is important to review whether the radiological characterization meets the requirements anticipated in the radiological characterization strategy and state in the radiological characterization report.

3.3 Methodology to Link the Results of Radiological Characterizations

The purpose of developing a radiological characterization plan is to support safe and economical decommissioning. This is ideal for preparation from the beginning of the NPP operation, and the linkage and synergy between the implementation goals and measures of each phase must be considered. Additionally, it is necessary to consider how radiological characterization information from the previous phase can be used in the next phase. It is also necessary to consider how radiological characterization information from the previous phase can be used in the next phase. This makes it possible to perform radiological characterization more efficiently during the decommissioning process by accurately recording and managing the various types of information collected during the operation period of the facility. In addition, important decisions must be made during the early phases for a decommissioning project to be successful. These decisions include the establishment of decommissioning strategies, evaluation and selection of decommissioning application technologies (decontamination and cutting technologies), the establishment of radiological conditions for materials and buildings for clearance, and waste (radioactive and non-radioactive) management measures. The judgment criteria for determining each decision start with the amount and distribution of radioactive material present within the facility, and this information can be secured through radiological characterization.

The main task of radiological characterization in the decommissioning and demolition phases is to investigate and evaluate radiological characteristics in the cutting and demolition processes of the system; however, it should be promoted as an extension of radiological characterization in the transitional phase. In addition, radiological characterization in the transitional phase is the basis for establishing a cutting and demolition plan. Based on this, it should go through the process of substantial confirmation through cutting and demolition in the decommissioning and demolition phases. Radiological characterization in the transitional phase can be replaced by assumptions or engineering judgments because physical access is difficult during radiation measurement or sampling, and actual measurement may not be possible owing to high radiation conditions. Therefore, in the decommissioning and demolition phase, the radiological characterization should have proceeded in the order of verifying the radiological characterization results of the transitional phase through actual measurements during the decommissioning process. In other words, the

results of radiological characterization in the transitional phase should be confirmed through radiological characterization in the decommissioning and demolition phases to review the appropriateness of the results. Additionally, it should be confirmed that the radiological characteristics measured in the previous phase remain valid without significant changes. In particular, it is important to identify the scale factors set in the transitional phase and minimize the change or invalidation of the scale factors through decommissioning. The invalidation of scale factors can lead to higher decommissioning costs and delays in the decommissioning process and can also affect the calculation of inventories at the radioactive waste repository for the disposal site of decommissioning waste.

Systematic data management is required to link the results of radiological characterizations for each stage. As shown in Tables 1 and 2, numerous data, including operational history, dose rates, activation calculation results, scaling factors, etc., are produced during radiological characterizations. Thus, a database of radiological characterizations is necessary to link the results of radiological characterizations for each stage and manage the collected data efficiently. Furthermore, it is also important to determine the key contents of radiological characterizations from a safety viewpoint. For example, the key contents, such as dose rates, airborne concentration, surface contamination levels, residual radioactivity, etc., produced in the transition phase can be used as important input data to provide optimal radiation protection to workers in the decommissioning and demolition phases.

Only when the radiological characterization for each stage is linked can the criteria for acceptance of the disposal of decommissioned waste be satisfied, and no nonconformity of disposal for final disposal occurs. Therefore, it is necessary to prevent significant changes in the radiological characteristics of the decommissioning and demolition phases through radiological characterization results obtained during the transitional phase. In particular, the results of radiological characterization, including scale factors calculated from the transitional phase, may become useless owing to system decontamination, cutting, and demolition. Therefore, this should be thoroughly verified and maintained in the decommissioning and demolition phases. This may prevent repetition and trial and error of radiological characterization [4, 6, 11].

4. Conclusion

Radiological characterization plays a key role in determining the technology to be used for decommissioning a facility by identifying the radiation source term and radioactive contamination present within the facility and determining the extent and nature of the radioactive contamination to be removed from the facility. In addition, radiological information should be recorded during the construction and operation phases of an NPP, and radiological characterization must systematically progress during the transitional period after a permanent shutdown. Therefore, this study presents the regulatory requirements for the radiological characterization of decommissioning NPPs, the procedures and methods of radiological characterization, and the linkage of radiological characterization in the transitional and decommissioning and demolition phases.

When developing a radiological characterization plan, the interconnections and synergies between each phase's implementation objectives and measures should be considered so that the radiological characterization information from the previous phase can be utilized in the next phase. This study suggests the following main implementation procedures for radiological characterization: operational history investigation, neutron irradiation and corrosion product inventory calculations, non-destructive radiation and radioactivity measurements, sampling, destructive radiation and radioactivity measurements, radiological characterization records, review of radiological characterization results, and report preparation for radiological characterization. This study presents specific implementation methods

and key issues in performing radiological characterization when decommissioning NPPs.

Radiological characterization produces a large amount of data. It is necessary to manage key data in terms of safety and accuracy. In particular, it is important to establish a unique coding system to maintain the traceability of radiological characterization data and records. It should also be accompanied by a scientific evaluation to control technical, administrative, and human factors that affect the quality of the results of the radiological characterization and to ensure that the type and quality of the data meet the objectives.

Radiological characterization in the decommissioning and demolition phases should be performed in a sequence that validates the results of the radiological characterization in the transitional phase for the decommissioning of SSCs and sites. Through this, it is possible to significantly reduce the items and contents of the radiological characterization that must be performed in the decommissioning and demolition phases and maintain the connection with the previous phase. The final data quality objective of the radiological characterization of NPP SSCs and sites is to dispose of radioactive waste and reuse sites. Linkage measures related to this objective were proposed in this study. This linkage measure should prevent the radiological characterization results from the transitional phase from becoming useless and ensure that the decommissioning waste complies with the acceptance criteria and is not declared unsuitable for final disposal. Therefore, the regulatory requirements, procedures, and methods for the radiological characterization of decommissioning NPPs presented in this study are expected to contribute to the establishment of a system in which radiological characterization can be efficiently performed in the future when decommissioning NPPs.

Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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