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Comprehensive Radiological Characterization and Decommissioning Plan: A Comparative Study of Wolsong-1 and German Nuclear Power Plants

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1. Introduction

The decommissioning of nuclear power plants requires a structured radiological characterization strategy to assess contamination, classify waste, and ensure regulatory compliance. A well-defined approach is essential to guarantee safety, minimize environmental impact, and optimize waste management. This study compares radiological survey methodologies applied to the decommissioning of Wolsong-1, a CANDU reactor in South Korea, and several pressurized water reactors (PWRs) in Germany, including Stade, Obrigheim, and Greifswald.

The comparison between South Korea and Germany highlights key differences in decommissioning strategies. South Korea has opted for an accelerated dismantling approach with a targeted decommissioning period of 10 years, whereas Germany follows a phased approach spanning several decades. This study provides insights into best practices for radiological surveys, sampling methodologies, and waste classification, contributing to the development of efficient and safe decommissioning frameworks.

2. Radiological Characterization Process

The radiological characterization process is structured into three sequential phases, each serving a distinct purpose in the decommissioning workflow.

Preliminary characterization establishes the radiological baseline before dismantling begins. It involves historical data reviews, initial radiation measurements, and predictive modeling to identify contamination zones. Characterization during dismantling is conducted in real time as structures are removed, refining the contamination profile and supporting waste classification. This phase ensures the safe handling of radioactive materials while preventing cross-contamination. Final release characterization is performed at the conclusion of decommissioning to confirm that residual radiation levels comply with site clearance criteria. The findings are documented in regulatory reports to obtain approval for site release.

3. Sampling Techniques and Radiological Analysis

3.1 Sampling Techniques

A variety of sampling techniques are employed throughout the decommissioning process to assess contamination and guide waste management strategies.

Table I: Sampling Techniques in Radiological Characterization

Sampling Technique	Description	Application
Scan-Only Surveys	Quick dose rate assessment using gamma radiation scanning.	Identifies high-contamination areas.
In-Situ Surveys	Real-time gamma spectrometry and dose rate mapping.	Determines contamination distribution in structures.
Method-Based Surveys	Wipe tests, air sampling, and direct material analysis	Detects airborne and surface radionuclides
Sampling and Laboratory Analysis Surveys	Collection of solid and liquid samples for detailed isotopic analysis.	Provides precise radionuclide quantification.

These techniques allow for a comprehensive assessment of radiological conditions, ensuring accurate contamination profiling at each stage of decommissioning.

3.2 Laboratory Analysis of Collected Samples

To quantify the presence of specific radionuclides and assess contamination levels, collected samples undergo detailed laboratory analysis using advanced radiochemical techniques. The following methods provide high-precision data essential for decontamination and waste classification.

Table Ⅱ: Laboratory Analysis Methods and Applications

Analysis Method	Target Radionuclides	Application
Gamma spectrometry	Co-60, Cs-137, Eu-152	Detection of gamma-emitting radionuclides
Alpha/beta counting	Pu-239, Sr-90	Quantification of alpha and beta emissions
Neutron activation analysis	Activated reactor materials	Identification of neutron-induced activation products
Liquid scintillation counting	Tritium, low-energy beta isotopes	Analysis of beta-emitting isotopes in liquid samples
ICP-MS (Inductively Coupled Plasma Mass Spectrometry)	Trace elements, radioactive metals	Measurement of trace radioisotope concentrations

4. Radioactive Waste Classification and Management

Proper waste classification is critical for ensuring safe disposal and regulatory compliance. Decommissioning activities generate low-level waste (LLW), intermediate-level waste (ILW), and high-level waste (HLW), each requiring tailored treatment strategies. Each waste category requires specific treatment and disposal strategies. LLW is subjected to decontamination procedures to enable potential recycling or is disposed of in near-surface repositories. ILW is encapsulated and stored in specialized long-term facilities until an appropriate disposal method is established. HLW requires extended cooling in interim storage before being transferred to deep geological repositories for final disposal.

Ensuring regulatory compliance is an integral part of the waste management process. In South Korea, decommissioning operations adhere to the Nuclear Safety Act and Radioactive Waste Management Act, which align with international guidelines such as MARSSIM (Multi-Agency Radiation Survey and Site Investigation Manual). In Germany, decommissioning follows EURATOM Directive 2013/59 and national disposal regulations. Globally, the IAEA GSR Part 6 sets safety standards for site decontamination, waste disposal, and clearance levels.

5. Conclusions

This study highlights the significance of structured radiological characterization, effective waste classification, and strict regulatory compliance in optimizing nuclear decommissioning processes. The comparison between Wolsong-1 and German decommissioning projects reveals the importance of tailoring radiological assessment methodologies to different reactor types, regulatory environments, and waste management challenges.

Future advancements in real-time radiation monitoring, AI-driven contamination analysis, and enhanced waste minimization strategies will further improve decommissioning efficiency and cost-effectiveness. As nuclear power plants worldwide reach the end of their operational lifespans, refining best practices in decommissioning and radioactive waste management will be essential to ensuring environmental safety and sustainability.

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