Managing Unexpected Events in Nuclear Decommissioning Using Case-Based Analysis and Mitigation Strategies

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Keywords : unexpected event, un-inventoried material, dismantling activities

1. Introduction

The decommissioning of nuclear facilities is a highly complex transitional phase, shifting a site from active operation to final clearance. While rigorous planning and comprehensive safety assessments are standard, the prolonged lifespan of these facilities and undocumented historical modifications inevitably lead to unexpected events.

These unforeseen circumstances compromise worker safety, cause severe project delays, and result in significant budget overruns. This paper analyzes the root causes of unexpected events originating specifically during the decommissioning phase itself, as outlined in the IAEA Technical Report (NW-T-2.8) [1]. By cross-referencing these origins with real-world case studies documented from un-inventoried radioactive liquids to hazardous material discoveries—this study aims to extract practical mitigation strategies. The ultimate objective is to provide decommissioning operators with robust methodologies for dynamic characterization, strict contractor management, and resilient contingency planning to safely navigate the inherent uncertainties of nuclear site remediation.

2. Origins of Unexpected Events and Mitigation Strategies

An analysis of historical case studies reveals that unexpected events are not merely legacy issues; they are frequently generated by the ongoing physical and administrative activities of the decommissioning phase itself. We categorize these origins into four critical areas and propose corresponding countermeasures based on lessons learned [2,3].

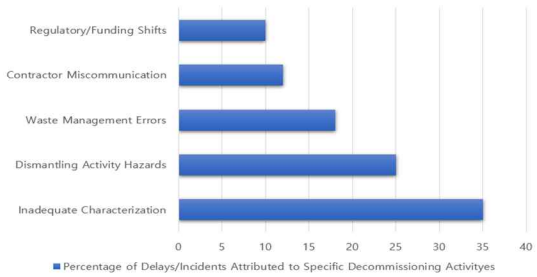

Fig. 1. Analysis of the Origins of Unexpected Events During the Decommissioning Phase

2.1 Inadequate Characterization and Planning

A primary catalyst for unexpected events during decommissioning is insufficient radiological and physical characterization. Over-reliance on outdated "as-built" operational records often leads to false negatives.

*Case Survey: In several instances, workers dismantling seemingly empty cooling circuits encountered trapped radioactive liquids that had not been included in the inventory. Furthermore, safety analyses failed to identify residual nuclear materials, such as uranium accumulation in system traps.

*Countermeasures: Decommissioning plans must enforce intrusive and dynamic characterization. Before any destructive work begins, collect direct-survey documents, 3D scanning, in-situ gamma spectrometry, and physical pipe-tapping must be conducted. Operators should assume historical blueprints are inaccurate until physically verified.

2.2 Hazards Emerging from Dismantling Activities

The aggressive nature of cutting, dismantling, and heavy lifting actively introduces new risks that were not present during normal operations.

*Case Survey: Demolition crews have uncovered hidden compartments containing unanticipated hazardous materials. A severe example is the unexpected discovery of asbestos insulation hidden within electrical wiring, which immediately halted work due to the risk of toxic airborne release. Additionally, dismantling activities can cause secondary spread of contamination.

*Countermeasures: Implement a "Stop Work" authority for all personnel upon encountering unknown substances. Deploy localized HEPA-filtered containment tents around cutting zones, and mandate pre-job Hazardous Material (Hazmat) surveys specifically targeting asbestos, lead, and PCBs, independent of radiological surveys.

2.3 Waste Management and Cross-Contamination Failures

Handling massive volumes of secondary waste creates administrative and logistical blind spots.

*Case Survey: The issue of cross-contamination and waste mismanagement is highly prevalent. In Case, radiologically cleared property was inadvertently re-contaminated while awaiting final disposition in a staging area. Furthermore, the failure to remove old radiological warning signage caused administrative chaos and a loss of public/regulatory confidence.

*Countermeasures: Establish strict, physically segregated staging zones with hard barriers for "cleared" versus "contaminated" assets. Implement an aggressive signage control policy where clearing a zone mandates the immediate, verifiable removal of all legacy hazard signs.

2.4 Operator versus Contractor Misalignment

Decommissioning heavily relies on specialized subcontractors. Miscommunication and differing safety cultures between the site operator and contractors often result in procedural deviations.

*Countermeasures: Adopt an integrated safety management model (e.g., Health and Safety Executive [4]. The site license holder must maintain ultimate oversight, ensuring that contractor Work Control Documents (WCDs) perfectly align with the site's historical knowledge and emergency response protocols [5].

Table 1. Origins of Unexpected Events During Decommissioning and Mitigation Strategies

Originating Phase	Root Cause & Case Study	Mitigation Strategy & Countermeasure
Characterization	Reliance on legacy data, Un-inventoried liquid in pipes	Intrusive verification, Non-destructive testing before cutting
Dismantling	Encountering hidden conventional hazards, Asbestos in wiring	Pre-job Hazmat survey, Universal “Stop Work” authority
Waste Management	Poor staging logistics, Re-contamination of cleared property	Strict physical segregation of cleared assets, Signage control
Contractor Interface	Miscommunication of hazard, Differing safety cultures	Integrated safety management system, Unified Work Control Documents

3. Summary and Future Work

Unexpected events during nuclear facility decommissioning are inevitable variables that require proactive, forward-looking preparation. Passive reliance on outdated historical records is no longer viable. To prepare for future decommissioning projects, operators should implement mandatory, intrusive physical characterizations prior to any dismantling activities.

Through an in-depth analysis of international decommissioning case studies, this paper identified four primary mechanisms that trigger unexpected events during the dismantling phase. First, the analysis shows that relying on legacy "as-built" records without conducting intrusive physical characterizations directly results in critical encounters with un-inventoried hazards, such as trapped radioactive liquids and residual nuclear materials. Second, the physical acts of cutting and dismantling actively generate new risk pathways, including the sudden exposure to conventional hazards like hidden asbestos. Third, logistical failures in secondary waste staging frequently lead to the cross-contamination of cleared assets. Finally, misalignment between operator and contractor safety cultures was found to amplify these procedural errors.

Based on these results, we conclude that implementing dynamic in-situ verification techniques (e.g., non-destructive pipe testing) and enforcing strictly segregated waste management protocols—integrated under a unified Work Control Document framework—are the most effective operational measures to minimize delays and safety incidents in nuclear decommissioning.

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