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DECOMMISSIONING OF NUCLEAR FACILITIES; STAGES, STRATEGIES AND FUTURE CHALLENGES: A REVIEW

Abstract
Decommissioning is the process whereby a nuclear facility, at the end of its economic life, is taken permanently out of service and its site made available for other purposes, such as parks, housing and institutions. Nuclear facilities needs to be dealt with, so that any contamination contained within may be disposed of without it becoming a danger to the public. However, there are challenges which cannot be overemphasized, these are, many different sites, fuel production, reactor site, reprocessing site, waste disposal, wide geographical spread, total estimated cost of decommissioning and clean up approximately. Decommissioning is characterized with some large scale capital projects which are associated with inherent challenges these are; complex with many technical challenges, strategies and plans exist for all the nuclear facility. The future challenges associated with decommissioning are acceleration, reduce cost and finding long lasting solutions to these unique technical challenges. To this effect, few solutions were recommended such as, accelerating (HOLISTIC APPROACH), reducing cost, finding solutions to unique technical challenges, maximizing Economic Recovery (MER), overcoming the variability of assets, planning and preparation, Knowledge and understanding of available technologies.

Key words: High Level Waste, Intermediate Level Waste, Low Level Waste, Decommissioning, Holistic Approach

1. Introduction

Decommissioning process involves removing the used nuclear fuel from the reactor, placing it into the used fuel pool, and in the long run into dry storage containers (which can be deposited on-site before transported off-site); dismantling systems or components containing radioactive products (For instance, the reactor vessel); and cleaning up or dismantling contaminated materials from the facility. Contaminated tools and materials can be disposed of in couple of ways: decontaminated on-site or removed and shipped to a waste-processing, storage or disposal facility. A process in which a nuclear facility, at the expiration of its commercial life, is taken permanently out of service and its site made available for other purposes. Liabilities is the costs involved in decommissioning; the processing, long term management, storage and final disposal of waste materials and spent fuel; and the environmental remediation of nuclear sites [1]. Decommissioning is characterized with some large scale capital projects which are associated with inherent challenges these are; complex with many technical challenges, strategies and plans exist for all the nuclear facility. The future challenges associated with decommissioning are acceleration, reduce cost and finding long lasting solutions to these unique technical challenges. To this effect there is the need to analyze the technical and future challenges of decommissioning and proffer possible remediation and solutions [2].

1.2 Stages of Decommissioning

- Initial Decommissioning
- Surveillance and maintenance
- Interim decommissioning
- Care and maintenance
- Final decommissioning
- Groundwater remediation
- Contaminated Land remediation

2. Factors Relevant to Selecting a Decommissioning Strategy

The conceptual basis for the selection of a decommissioning strategy can be found in the IAEA's "Principles of Radioactive Waste Management" (PRWM). Principles of protection of and burden on future generations but they are not prescriptive in nature. The IAEA's Member States are given the flexibility of evaluating how to implement these principles as reflected in derived safety guides such as reference [3, 4]. It can be generally assumed that undue delays in decommissioning of nuclear facilities should be prevented, but the interpretation of "undue" is left to national authorities. These factors may range from Radiological, Chemical, Conventional, Environmental, waste arising and national waste management strategy, spent fuel management strategies, physical conditions of the plant, owner's interest, including planned use of site, availability of technology and other resources, social considerations, decommissioning cost and funding and radiological exposures.

2.1 Decommissioning Strategies

Two of the basic decommissioning strategies for a nuclear facility are:

- Immediate dismantling, and
- Long-term storage followed by dismantling.

Currently, a third strategy is being considered, namely in situ disposal. This alternative involves encasement of the radioactive structures, systems and components in a structurally long lived substance, such as concrete. This option is known as ENTOMB in the USA. However, a US Nuclear Regulatory

Commission (NRC) document states "Currently, ENTOMB is not considered a viable option for reactor decommissioning because some of the long-lived radioisotopes present at the facility may not decay to acceptable levels within the sixty-year period." [4]

Table 1.

Radioactive Waste Management Principles Relevant to Selecting a Decommissioning Strategy [5].

Principle 1	**PROTECTION OF FUTURE GENERATIONS** Radioactive waste is managed in a way that the predicted impacts on the health of future generations do not exceed relevant levels that are acceptable today.
Principle 2	**BURDEN OF FUTURE GENERATIONS** Radioactive waste is managed in a way that the will not impose undue burden on future generations.

3. Radiological Exposures

The removal of the reactor fuel or process materials from a facility and, if practicable, from the site removes the main radiological risk presented by that facility. However, a residual risk to workers, the public and the environment will remain during decommissioning based on the residual radioactivity. This risk will be most significant during the immediate post operational and initial and final decommissioning phases when physical work is being carried out on the facility. One of the purposes in placing a facility in a prolonged period of safe enclosure between the initial and final phases of decommissioning is to achieve some radiological advantage for subsequent decommissioning. This will be primarily due to radioactive decay of radionuclides present and includes:

- The reduction in local dose rates and consequent reduction in operator doses;
- The reduction of the radiological consequences of any accidents during dismantling;
- The reclassification of some radioactive wastes [6]

3.1 Decommissioning Strategies Worldwide

The choice between the two prevailing decommissioning strategies, deferred or direct dismantling, depends on a variety of factors, which are summarized in Table 2:

Table 2:
Principal Decision Making Criteria for Decommissioning

Decision criteria for deferred dismantling
• Lack of availability of a repository
• Lack of funds for direct dismantling
• Radioactive decay of some radionuclides, and consequently:
• Reduction of local dose rates
• Reclassification of some radioactive wastes
Decision criteria for direct dismantling
• Availability of facility staff
• Allows re-employment of staff
• Use of specific expertise
• Use of existing infrastructure, including an available repository
• Experience with licensing procedures
• No long-term site commitment
• Unrestricted use of the grounds for other purposes
• Public and political acceptance

4. Decommissioning strategies

4.1 Immediate or Early Dismantling

Immediate dismantling commences shortly after shut down, if necessary following a short transition period to prepare for implementation of the decommissioning strategy. Decommissioning is expected to commence after the transition period and continues in phases or as a single project until an approved end state including the release of the facility or site from regulatory control has been reached.

4.2 Deferred Dismantling

Deferred dismantling is a strategy in which a facility or site is placed in a safe condition for a period of time, followed by decontamination and dismantling. During the deferred dismantling period, a surveillance and maintenance programme is implemented to ensure that the required level of safety is maintained. During the shutdown and transition phases, facility specific actions are necessary to reduce and isolate the source term (removal of spent fuel, conditioning of remaining operational or legacy waste, etc.) in order to prepare the facility/site for the deferred dismantling period [7, 8].

Fig. 1. Manual Decommissioning Technique

Fig. 2. Remote Decommissioning Handling

4.3 Waste Categorization and Disposal Method

High Level Radioactive Waste (HLW) > Intermediate Level Radioactive Waste (ILW) > Low Level Radioactive Waste (LLW) > free release/recycle.

5. Methodology

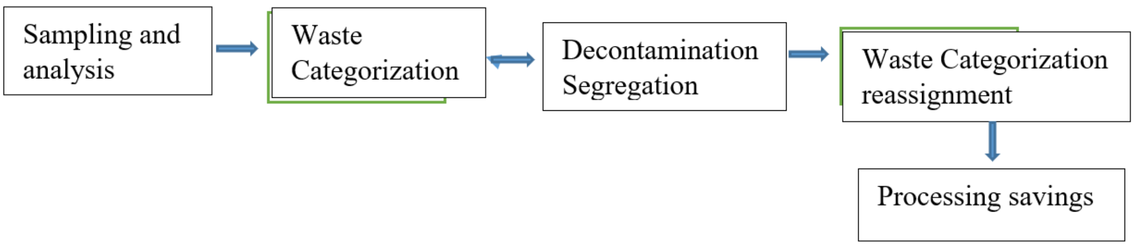

Figure 3. Waste Categorization and Disposal Method Model

6. Future Challenges

The alternative of leaving a facility in long-term safe storage may cause a specific waste management problem in the future. With future disposal facilities so uncertain, a number of utilities have declared that they are unprepared to take the risk. The prospect of not having a disposal facility available at any cost may greatly overshadow the economics involved in the long-term build-up of decommissioning funds. It seems that immediate decommissioning will prevail in some countries that have limited waste disposal capacities. In fact, recent decisions appear to be driven by the desire to take advantage of existing disposal facilities while the option is still available and before disposal costs escalate to unbearable levels (for instance, in the USA) [9, 10].

7. Conclusion

All the identified major factors influence decommissioning strategies to a greater or lesser extent. The selection of a decommissioning strategy needs to be based on the evaluation of all relevant factors. Techniques may be used such as multi-attribute analyses that would consider all the relevant factors, constraints and conditions, their interactions and weights to select the appropriate strategy. However, some vital solutions and remedy to the challenges are accelerating (HOLISTIC APPROACH), reducing cost, finding solutions to unique technical challenges, maximizing Economic Recovery (MER), overcoming the variability of assets, planning and preparation, Knowledge and understanding of available technologies.

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RELIABILITY AND OPTIMIZATION OF MAINTENANCE OF THE IRT-T REACTOR EQUIPMENTS (TPU)

1. Introduction

IRT-T [1] is a pool-type research reactor that uses distilled water as a moderator, coolant, and top shield. The reactor is intended for solid-state physics research, neutron activation study of elemental composition of substances, radionuclide synthesis, silicon doping, and neutron radiography. The reactor core of this reactor is made up of IRT-3M fuel and it uses beryllium as a reflector [2]. At present, close attention has been devoted to the reliability and safety of nuclear power plants, small modular reactors, and research reactors compared to the past. This was because of accidents that happened at Three Mile Island (TMI), the Chernobyl Nuclear Power Plant, and Fukushima. Because the cooling systems of research reactors play a big part in how they work, it would be good for reliability and safety tests to be done on them.

2. Major components of IRT-T Reactor Coolant System (RCS)

The Reactor Coolant System (RCS) of an IRT-T reactor consist of primary and secondary loops. The primary circuit which consists of pumps, heat exchangers, fittings, pipelines and holding tank. To cool the primary circuit water in the heat exchangers, process water of the secondary circuit is used. The second circuit includes a cooling tower cooling tower of sprinkler design with the secondary coolant flow rate up to 2100m3/s, four pumps, five heat exchangers, and a system of circulating water supply pipelines as can be shown in figure 1 [1,2].