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Safety Assessment Tools for Disposal Facilities of Decommissioning Waste

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1. Introduction

As a result of the decommissioning of nuclear power plants, a wide range and quantity of radioactive materials will be generated. Some of these materials can be recycled or reused but most of them must be managed as radioactive waste. Therefore, the development and implementation of appropriate strategies for the processing and disposal of decommissioning waste has become an important issue. The appropriate strategies for decommissioning waste disposal have to be based on waste category data and their characteristics. In addition, the appropriate disposal methods based on the characteristics of decommissioning waste have to be implemented and the safety assessment of different disposal facilities has to be made for the safe management of decommissioning waste. In this study, we suggested appropriate tools for the safety assessment of several disposal facilities of decommissioning waste.

2. Method and Results

2.1. Sources of decommissioning waste

The generation of decommissioning waste depends on the plant size and design, construction materials used, operational history, and activities performed. In general, decommissioning waste can be classified as primary waste, secondary waste, and contaminated tools and equipment [1]. Primary decommissioning waste refers to waste generated during dismantling activities. Primary waste varies widely in terms of type, activity, size and volume, and consists of both activated and contaminated components. Secondary waste refers to waste generated during various decontamination and dismantling activities, e.g. decontamination of metallic components or flushing of systems to reduce the amount of primary waste. Contaminated tools and equipment refers to materials employed during the decontamination and dismantling of a nuclear facility that become contaminated during use.

2.2. Radiological characteristics of decommissioning waste

Radiological characterization is necessary to provide reliable information on the quantity and type of radionuclides, their distribution and their physical and chemical states for the successful implementation of decommissioning plans. Characterization data can be used for making further characterization work plans to provide an exposure dose and risk assessment and to identify the types of safety and radiological protection for the protection of workers, the general public, and the environment.

Following a shutdown and discharge of irradiated fuel, the radionuclide inventory of a nuclear reactor falls into two categories: neutron activation materials and contaminated materials. The neutron activation materials are located in and near the core and have been irradiated by neutrons. The radioactive contamination processes are the transport and leachate of corrosion products, and the erosion products or fission products and actinides. Table I shows the calculated activities of important radionuclides from reactor activation in the major components of a PWR. Table II shows the quantities of radioactive products deposited in the interior of the reactor components. Because the activity of important radionuclides decays after a reactor shutdown, the activities as a function of time have to be estimated. A typical radionuclide decay curve is given in Fig.1.

The principal activation products present in reactor materials at shutdown are ^{55}Fe, ^{60}Co, ^{59}Ni, ^{63}Ni, ^{39}Ar, and ^{94}Nb (in steel); ^{3}H, ^{14}C, ^{41}Ca, ^{55}Fe, ^{60}Co, ^{152}Eu, and ^{154}Eu (in reinforced concretes) and ^{3}H, ^{14}C, ^{152}Eu, and ^{154}Eu (in graphite). In terms of the radiation levels, ^{60}Co is the most predominant radionuclide. For steel, ^{55}Fe and ^{60}Co account for the major part of the inventory in the first ten years after a shutdown [2].

Table I. Radionuclide Inventory of PWR (Trino) [2]

Radionuclides	Activity (Bq)
Fe-55	3.01E+15
Co-60	1.89E+15
Ni-63	7.26E+14
Mn-54	2.81E+13
Ni-59	5.97E+12
H-3	3.73E+12
Cs-134	4.63E+12
Ar-39	8.55E+12
Ag-108m	4.20E+11
Total	5.70E+15

Assumptions: 870Mwt, 23 years of operation, 10.6 EPFY
5 years after shutdown

The most abundant radionuclides in contamination residues still present 10–20 years after the reactor shutdown are ^{3}H, ^{60}Co, ^{55}Fe and ^{137}Cs. After about 20–30 years, the most abundant radionuclides are ^{63}Ni, ^{137}Cs, ^{60}Co and ^{90}Sr. The long lived transuranic actinides such as ^{241}Am, $^{238, 239, 240}Pu$ and ^{244}Cm do not become significant parts of the radionuclide inventory until after about 100–200 years [2].

Table II. Quantities of radioactive products deposited in the interior of the reactor components (PWR) [2]

Components	Activity (Bq)
Reactor vessels and internals	4.8E+12
Steam generators	1.6E+14
Pressurizer	1.5E+11
Piping (except reactor heat transfer circuits)	2.2E+12
Reactor heat transfer circuits	6.0E+12
Total	1.8E+14

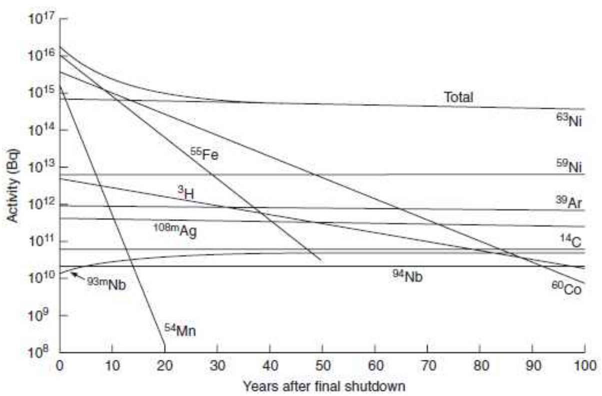

Fig. 1. Decay curve of principal radionuclides in PWR

2.3. Classification of radioactive wastes and disposal methods

According to the IAEA's general safety guide report related to the classification of radioactive wastes [3], radioactive wastes are classified into six categories: high level waste (HLW), intermediate waste (ILW), low level waste (LLW), very low level waste (VLLW), very short-lived waste (VSLW), and exempt waste (EW). The regulatory body in Korea, the NSSC (Nuclear Safety and Security Commission) released a notice related to the classification of radioactive waste [4]. According to this notice, radioactive wastes are classified into four categories (HLW, ILW, LLW, VLLW), and the clearance levels are described. In addition, the appropriate disposal methods are suggested for each radioactive waste class, which are shown in Fig. 2.

2.4. Safety assessment tools for disposal facilities of decommissioning wastes

There may be several kinds of disposal facilities for decommissioning wastes depending their characteristics: deep geological disposal, cavern disposal, shallow land disposal, and landfill. For the safe management of decommissioning waste disposal, the safety assessment of potential disposal methods has to be made. In this study, we consider three kinds of disposal methods for the disposal of decommissioning wastes; landfill, shallow land burial, and deep geological disposal. In addition, we suggested appropriate safety assessment tools for each disposal method.

First, we consider the RESRAD code [5] family for the safety assessment of a landfill of decommissioning waste. This RESRAD code has been used widely in many government agencies and institutions in several countries including Korea as well as the USA. The exposure pathways for the critical population group in the RESRAD code are direct exposure to external radiation from a contaminated soil material; internal dose from the inhalation of airborne radionuclides; internal dose from the ingestion of plant foods, meat and milk, drinking water, and fish; and contaminated soil, as in Fig. 3.

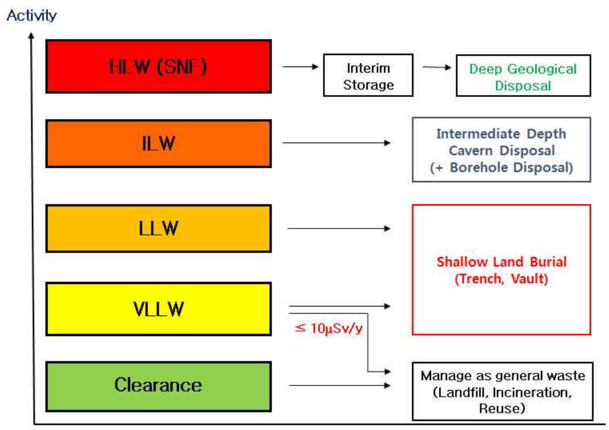

Fig.2. Classification of radioactive wastes

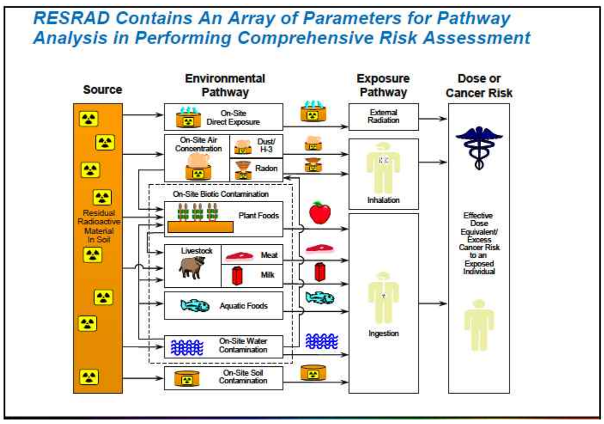

Fig.3. Illustration of exposure pathways in RESRAD code.

Second, we suggest the GSTRENCH code [6] for a safety assessment of a trench-type surface disposal system. This is a simple and effective model and a

GoldSim template program, by which a probabilistic safety assessment of a conceptual trench-type repository for low- and intermediate level radioactive waste disposal can be carried out under various nuclide release scenarios. A schematic diagram of the GSTRENCH code is shown in Fig.4.

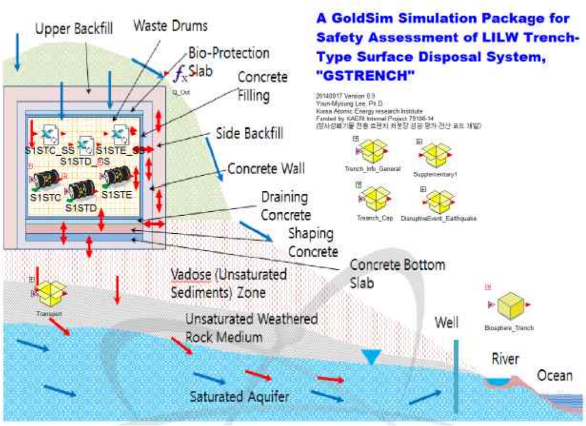

Fig.4. Schematic diagram of GSTRENCH code.

Third, we suggest the K-PAM (KARRI Performance Assessment Model) code [7] for the safety assessment of a deep geological disposal system. This is a risk-based safety assessment model developed by coupling MATLAB and GoldSim for the total system performance of a conceptual geological disposal system for radioactive wastes from pyro-processing based on the KURT environment. It was partially verified by comparing the results of K-PAM and those of a comparable process model using COMSOL. In addition, the K-PAM code was demonstrated using three scenarios: a reference scenario, a deterministic complex scenario, and a probabilistic complex scenario. The schematic diagram of the K-PAM code is shown in Fig.5.

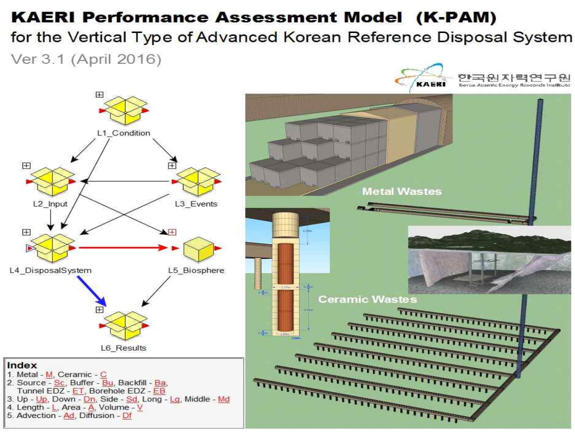

Fig.5. Schematic diagram of K-PAM code.

3. Summary and Conclusions

We suggested the use of safety assessment tools for the different disposal methods of decommissioning waste depending on their characteristics. The RESRAD code, GSTRENCH, and K-PAM code can be used for a safety assessment of a landfill site, shallow land burial, and a deep geological disposal facility, respectively, although they have to be slightly modified to consider all radionuclides in the decommissioning waste. By applying these safety assessment tools to various disposal facilities of decommissioning wastes, we can secure safe management strategies and the suitability of their disposal based on the safety assessment results.

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