A Study on the Review of Concrete Waste Generated by Decommissioning of Nuclear Power Plant

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1. Introduction

According to IAEA PRIS in March 2020, total number of nuclear power plant (NPP) 442 units are in operation around the world, among them over 30 years old NPPs are 67.9% [1]. Also, recently permanent shutdown of Wolsong-1 was determined following to Kori-1 in Korea. And the number of old nuclear power plant will be permanent shutdown in the future.

Especially, domestic institution has no experience in decommissioning of commercial nuclear power plant in Korea. Therefore, technologies and regulations for decommissioning of nuclear power plant should be prepared in Korea. Most of all, disposal of waste generated decommissioning of nuclear power plant is expected to be the biggest issue in Korea.

According to previous cases, most wastes of decommissioning consist of metal and concrete.

Especially, concrete waste is insignificantly surface contaminated except for radioactive bio-shields, and most of them are clearance waste, very low level and low-level wastes. In this study, concrete waste generated decommissioning of nuclear power plant is analyzed through previous studies and cases.

2. Concrete Waste Classification and Characteristic

2.1 Classification of Radioactive waste

As shown in table I, classifications of radioactive waste for disposal method and characteristic is summarized.

This criteria are separated according to recommendation of new radioactive waste classification for safety analysis of international disposal facilities in 2009 by IAEA.

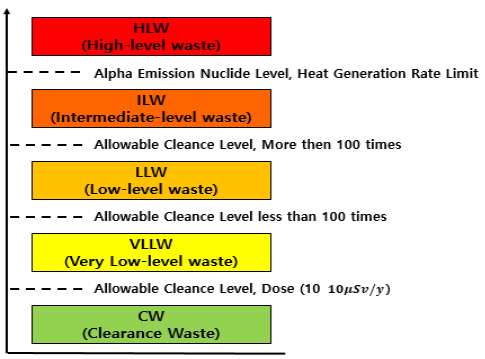

Fig. 1. Classifications of radioactive waste in Korea

Table I: Classifications of radioactive waste and methods of disposal [2, 3]

Classification	Waste level
High Level Waste (HLW)	· Heat dissipation is an important factor · Activity concentration in the range of 10^4-10^6 TBq/m^3 · Deep geological disposal · Greater than 4,000 Bq/g (Concentration of Alpha Emitter with $T_{1/2}$ > 20 year) · Heat generation > 2 KW/M^3
Intermediate Level Waste (ILW)	· Long lived radionuclides · Needs a greater degree of isolation and containment than near surface disposal · Disposal at depth of between a few tens and a hundreds of meters
	$\sum_{i=1}^{n} \frac{Ai}{DCi} > 1$
Low Level Waste (LLW)	· Needs of isolation and containment for hundreds of years · Limit - 400 Bq/g for alpha radionuclides - Up to kBq/g for Beta / gamma radionuclides · Disposal at depth from the surface down to 30m
	$\sum_{i=1}^{n} \frac{Ai}{CWi} > 100 \,\&\, \sum_{i=1}^{n} \frac{Ai}{DCi} \le 1$
Very Low Level Waste (VLLW)	· One or two orders of magnitude above the level for exempt waste · Disposal in engineered surface landfill type facilities
	$1 < \sum_{i=1}^{n} \frac{Ai}{CWi} \le 100$
Clearance Waste (CW)	· Exclusion, exemption, clearance waste · IAEA RS-G.1.7
	$\sum_{i=1}^{n} \frac{Ai}{CWi} \le 1$

*A_i: Concentration (Bq/g) of the radionuclide in Radiowaste
DC_i: Upper limits of Concentration (Bq/g) of the radionuclide for Disposal Criteria
CW_i: Upper limits of Concentration (Bq/g) of the radionuclide for Clean Waste

2.2 Concrete Waste Generated Decommissioning

According to IAEA, the estimated concrete waste generated decommissioning of nuclear power plant. It

depends on the type, power, operational history and impurities in cement.

Table II: Typical radioactive material generated from decommissioning [4]

Radioactive material generation	**900-1300 MWe PWR (ton)**
Activated steel	650
Activated concrete	300
Contaminated ferritic steel	2400
Steel likely to be contaminated	1100
Contaminated concrete	600
Contaminated lagging	150
Contaminated technological	1000

As show in table II, this is example of volume for concrete waste generated during decommissioning of nuclear power plant.

The volume of concrete wastes for Connecticut Yankee NPP (560MWe, PWR) and Maine Yankee NPP (860MWe, PWR) is 83.5% and 52% among total waste and most of them are LLW, VLLW.

Table III: Connecticut Yankee NPP decommissioning waste [5]

Radioactive waste	**Amount (ton)**	**Percent (%)**
Asphalt	318	0.3
Primary components & LLW	1,315	1.1
Concrete waste	100,539	83.5
Muck layed in water way	2,688	2.2
Mixed waste	60	0.0
Soil	15,468	12.9
Total waste	120,388	100.0

Table IV: Maine Yankee NPP decommissioning waste [6]

Radioactive waste	**Amount (ton)**	**Percent (%)**
Concrete waste	63,485	64.4
Soil	22,468	22.8
Commodities	8,761	8.9
Distributables	1,357	1.4
Large equipment	2,494	2.5
Total waste	98,568	100.0

2.3 Characteristics of Concrete Waste

Radioactive concrete waste is classified according to the pollutant. It is classified into surface-contaminated concrete waste and radioactive concrete waste.

Surface contaminated concrete is contaminated with cement paste by leakage of coolant using primary system. The depth of contamination for concrete within 1-10mm [7, 8]. Most of all, contaminants present on the surface are CW, VLLW, and LLW.

Radioactive concrete, the contamination source is inside the bio-shield within 100cm. Radioactive concrete are produced by reaction between unidentified impurities in cement and neutrons for a long time. At the time of the construction of the nuclear power plant in the past, the properties of concrete have not been evaluated accurately [9]. Therefore, evaluation of accurate volume of radioactive concrete should have conducted before decommissioning.

Among various technologies according to decommissioning of concrete, characterization to analysis volume of waste of concrete is important technology. This is that the distribution of nuclides according to depth should be accurately analyzed. It should be sorted and disposed of according to the level of the waste using smear test and core drilling.

2.4 Concrete Nuclide

As show in table V, nuclear power plants that have analyzed pollutants. This power and type of nuclear power plants are similar to Kori-1.

Radioactive nuclide generated concrete waste was commonly H-3, C-14, Fe-55, Co-60, Ni-63, Cs-134, Cs-137, Eu-152, Eu-154.

Table V: PWR Type NPP Nuclide [5, 7, 10, 11]

NPPs Name	Zion Solution	Connecticut Yankee	Maine Yankee	TRINO
Power Rating (MWe)	1040	560	860	870
Type	PWR	PWR	PWR	PWR
Nuclide	H-3	H-3	H-3	Fe-55
	C-14	C-14	C-14	Co-60
	Fe-55	Co-60	Fe-55	Ni-63
	Ni-59	Nb-94	Ni-63	Mn-54
	Co-60	Tc-68	C0-60	Ni-59
	Ni-63	Ag-108m	CS-137	H-3
	Sr-90	Cs-134	CS-134	Cs-134
	Cs-134	CS-137	Eu-154	Ar-39
	Cs-137	Eu-152	Ca-41	Ag-108m
	Eu-152	Eu-154		
	Eu-154	Am-241		

3. Conclusions

The previous cases of concrete waste generated during decommissioning of nuclear power plant, a large amount of concrete waste was generated. Most wastes have a low concentration of pollutants.

However, the uncertainty of impurities contained in concrete should be considered.

For successful decommissioning in Korea, it is necessary to develop measurement technology that can accurately classify wastes in consideration of cost reduction, waste volume reduction, and safety.

4. Acknowledgement

This work was supported by the National Research Foundation of Korea (NRF) grant funded by the Korean government (MSIP:Ministry of Science, ICT and Future Planning) (No. 2017M2B2B1072888)

This work was supported by the Human Resources Program in Energy Technoloy of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) granted financial resource from the Ministry of Trade, Industry & Energy, Republic of Korea (No. 20184030201970)

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