DOI: 10.15669/pnst.6.52

Progress in Nuclear Science and Technology
Volume 6 (2019) pp. 52-57

TECHNICAL MATERIAL

A study on the possibility of clearance for radioactive metal wastes from decommissioning of nuclear power plants in Korea

Jong-Soon Song, Dong-Min Kim and Sang-Heon Lee*

Chosun University, 309 Pilmun-Daero, Dong-Gu, Gwangju, 501-759, Republic of Korea

Decommissioning wastes generated from decommissioning of a nuclear power plant are mainly comprised of metal wastes. These metal wastes are considered to be possible of clearance by appropriate management. Accordingly, this study is carried out to assess the possibility of clearance from the viewpoint of worker safety during the clearance of metal wastes with the aim of reducing the disposal amount of radioactive metal wastes during the decommissioning of a nuclear power plant. The assessment targets were the Boron Recovery Tank pipes and pressurizer, and the RESRAD-RECYCLE computer code was used to assess the radiological risk of each scenario. The assessment results showed that the BRT pipes met the permissible radiation dosage for clearance and the pressurizer met the permissible radiation dosage for clearance after 23 years in case of the decontamination factor of 1,000 and after 5 years in case of the decontamination factor of 10,000, respectively.

Keywords: decommissioning; decontamination factor; clearance; recycle; metal waste

1. Introduction

A nuclear power plant (NPP) becomes the end of design life after continued operation, and therefore will be inevitably decommissioned. A large amount of radioactive wastes are generated in the event of decommissioning of a NPP. It is expected that most of the wastes are classified into very low-level radioactive wastes (VLLW) and it is considered that the most of the VLLW wastes are mainly comprised of the metal wastes. It is considered that the disposal amount of these wastes can be considerably reduced by clearance through appropriate management. Therefore, in this study, in order to show the possibility of clearance of radioactive metal wastes from future decommissioning of NPPs, the risk according to the clearance scenario was assessed using the RESRAD-RECYCLE code. In addition, a comparative analysis was conducted by applying the input value that meets the condition for domestic clearance.

2. Main subject

2.1. Local regulation on clearance

Recently, Republic of Korea (ROK) revised the deregulation provision, which stipulates the “Radioactive Wastes below the Disposal Limit” as wastes to be deregulated, in the establishment of a new radioactive waste classification system according to the recommendation of International Atomic Energy Agency (IAEA). According to the notice of the Nuclear Safety and Security Commission (NSSC), it is possible to dispose the radioactive wastes below the clearance threshold and the radioactive wastes proven to meet the permissible dosage for clearance by the methods such as incineration, burial, reuse, and so on. The permissible dosage for clearance has to meet less than 10μSv per year for individual and less than 1man·Sv per year for group [1].

2.2. Assessment code

2.2.1 Introduction of assessment code

The RESRAD-RECYCLE computer code was developed by Environmental Assessment Division (EAD) of Argonne National Laboratory (ANL) in 2003 under the support of the U.S. Department of Energy (DOE) for the purpose of assessing the radiological impacts during the recycling and reuse of radioactive metal wastes subject to deregulation. **Figure 1** shows the conceptual procedure of RESRAD-RECYCLE. The RESRAD-RECYCLE code is able to be used to assess 41 scenarios and 54 nuclides for assessment of potential exposure dosage and hazard for the workers collecting, transporting and handling radioactive metal wastes and the public who use consumables and public goods. The scenarios of RESRAD-RECYCLE computer code are shown in the **Table 1** [2].

2.2.2 Input parameters to assessment code

Table 2 shows the input parameters for assessment of 41 scenarios of the RESRAD-RECYCLE code.

*Corresponding author. Email: jssong@chosun.ac.kr

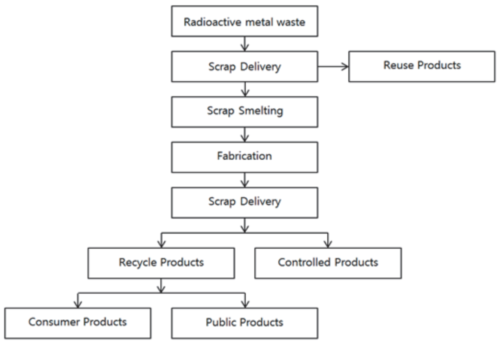

Figure 1. A conceptual diagram of the recycling process.

Table 1. Scenario of RESRAD-RECYCLE computer code.

Scenario			
Scrap Delivery	Scrap Cutter	Product Distribution	Product Loader
	Scrap Loader		Product Driver
	Scrap Driver		Sheet Assembler
	Public Dose		Warehouse Worker
Scrap Smelting	Scrap Processor	Consumer Products	Parking Lot
	Smelter Yard Worker		Room/Office
	Smelter Loader		Appliance
	Furnace Operator		Automobile
	Baghouse Processor		Ship/Boat
	Refinery Worker		Office Furniture
	Ingot Caster		Home Furniture
	Small Objects Caster		Frying Pan
	Slag Worker		Beverage Can
Ingot Delivery	Ingot Loader	Public Products	Pavement
	Ingot Driver		Building(With rebar)
Initial Fabrication	Storage Yard Worker		Building(With Geodesic Dome)
	Sheet Maker		Bridge
	Coil Maker	Controlled Products	Shielding Block
Final Fabrication	Sheet Handler		Radioactive Waste Container
	Coil Handler	Reuse Products	Tool Reuse
			Building Reuse

Table 2. Input parameters of RESRAD-RECYCLE code.

Input variables according to each scenario	
Ingestion Dose Conversion Factor (DCF)	Respiratory Protection Fraction
Inhalation DCF	Dust fraction from slag
Exposure Duration (hr/yr)	Emission Rate (1/hr)
Inhalation Rate (m/hr)	Surface Transfer Fraction
Ingestion Rate (g/hr)	Ventilation Rate (1/hr)
Contaminant Dust Loading (g/m^3)	Room Volume (m^3)
Respirable Fraction	Source Density (g/m^3)
Dilution Fraction	Source Thickness (cm)
Initial Decay Time (yr)	Source Radius (cm)
Number Of Individuals	Number of Sides
Population Exposure Duration (hr/yr)	Distance (cm)

2.3. Deduction of input parameters that meet the domestic conditions

The RESRAD-RECYCLE computer code has various input parameters for each scenario and the assessment result can be computed depending on these input parameters. Therefore, to use the assessment code, it is necessary to modify the input parameters of the in accordance with domestic conditions. In ROK, however, as there is insufficient worker data about the clearance process, it is difficult to change all these input parameters to meet the domestic condition. Accordingly, key input parameters among the various input parameters in the assessment code by sensitivity analysis were selected in this section. In addition, the key input parameter values for assessment suitable for the domestic situation were obtained by investigation of domestic cases for clearance. These will be used for worker risk assessment so as to increase the reliability of the results of the final assessment.

2.3.1 Sensitivity analysis

To conduct the sensitivity analysis, the code was run by applying proportions (50%, 100%, and 150%) to the input parameter values of the scenario in the code, and the result values were compared. The representative scenario for the sensitivity analysis and the background of selecting the input parameters are stated as follows. First, since the scenario does not greatly affect the sensitivity analysis, 12 key worker scenarios were randomly selected. The input parameters such as work time, inhalation rate, and ingestion rate, which can directly affect worker exposure, were selected among various input parameters as key assessment factors. The result of the sensitivity analysis was shown that there was little change in the inhalation rate and ingestion rate. However, there was a considerable change depending on the proportion that is work time applied. Accordingly, work time was selected as a key input parameter. The results of the sensitivity analysis are shown in **Tables 3-5** [3].

Table 3. Result of Sensitivity analysis (Work time).

Work time (μSv/yr)			
Scenario	50%	100%	150%
Scrap Cutter	$1.74X10^{-2}$	$3.48X10^{-2}$	$5.22X10^{-2}$
Scrap Loader	$2.48X10^{-2}$	$4.97X10^{-2}$	$7.45X10^{-2}$
Scrap Truck Driver	$2.18X10^{-2}$	$4.36X10^{-2}$	$6.54X10^{-2}$
Scrap Processor	$1.78X10^{-2}$	$3.55X10^{-2}$	$5.33X10^{-2}$
Smelter Yard Worker	$1.61X10^{-1}$	$3.21X10^{-1}$	$4.82X10^{-1}$
Smelter Loader	$2.98X10^{-2}$	$5.96X10^{-2}$	$8.94X10^{-2}$
Furnance Operator	$1.07X10^{-1}$	$2.13X10^{-1}$	$3.20X10^{-1}$
Baghouse Processor	$4.74X10^{-3}$	$9.48X10^{-3}$	$1.42X10^{-2}$
Refinery Worker	$1.17X10^{-1}$	$2.35X10^{-1}$	$3.52X10^{-1}$
Ingot Caster	$5.85X10^{-2}$	$1.17X10^{-1}$	$1.76X10^{-1}$
Small Objects Caster	$2.70X10^{0}$	$5.40X10^{0}$	$8.09X10^{0}$
Slag Worker	$1.13X10^{-8}$	$2.26X10^{-8}$	$3.39X10^{-8}$

Table 4. Result of Sensitivity analysis (Inhalation rate).

Inhalation rate (μSv/yr)			
Scenario	50%	100%	150%
Scrap Cutter	$3.47X10^{-2}$	$3.48X10^{-2}$	$3.48X10^{-2}$
Scrap Loader	$4.97X10^{-2}$	$4.97X10^{-2}$	$4.97X10^{-2}$
Scrap Truck Driver	$4.36X10^{-2}$	$4.36X10^{-2}$	$4.36X10^{-2}$
Scrap Processor	$3.55X10^{-2}$	$3.55X10^{-2}$	$3.55X10^{-2}$
Smelter Yard Worker	$3.21X10^{-1}$	$3.21X10^{-1}$	$3.21X10^{-1}$
Smelter Loader	$5.96X10^{-2}$	$5.96X10^{-2}$	$5.96X10^{-2}$
Furnance Operator	$2.13X10^{-1}$	$2.13X10^{-1}$	$2.13X10^{-1}$
Baghouse Processor	$9.48X10^{-3}$	$9.48X10^{-3}$	$9.48X10^{-3}$
Refinery Worker	$2.35X10^{-1}$	$2.35X10^{-1}$	$2.35X10^{-1}$
Ingot Caster	$1.17X10^{-1}$	$1.17X10^{-1}$	$1.17X10^{-1}$
Small Objects Caster	$5.40X10^{0}$	$5.40X10^{0}$	$5.40X10^{0}$
Slag Worker	$2.09X10^{-8}$	$2.26X10^{-8}$	$2.44X10^{-8}$

Table 5. Result of Sensitivity analysis (Ingestion rate).

Ingestion rate (μSv/yr)			
Scenario	50%	100%	150%
Scrap Cutter	$3.45X10^{-2}$	$3.48X10^{-2}$	$3.51X10^{-2}$
Scrap Loader	$4.96X10^{-2}$	$4.97X10^{-2}$	$4.98X10^{-2}$
Scrap Truck Driver	$4.36X10^{-2}$	$4.36X10^{-2}$	$4.36X10^{-2}$
Scrap Processor	$3.52X10^{-2}$	$3.55X10^{-2}$	$3.58X10^{-2}$
Smelter Yard Worker	$3.20X10^{-1}$	$3.21X10^{-1}$	$3.23X10^{-1}$
Smelter Loader	$5.95X10^{-2}$	$5.96X10^{-2}$	$5.97X10^{-2}$
Furnance Operator	$2.13X10^{-1}$	$2.13X10^{-1}$	$2.13X10^{-1}$
Baghouse Processor	$9.46X10^{-3}$	$9.48X10^{-3}$	$9.50X10^{-3}$
Refinery Worker	$2.35X10^{-1}$	$2.35X10^{-1}$	$2.35X10^{-1}$
Ingot Caster	$1.17X10^{-1}$	$1.17X10^{-1}$	$1.17X10^{-1}$
Small Objects Caster	$5.39X10^{0}$	$5.40X10^{0}$	$5.40X10^{0}$
Slag Worker	$1.31X10^{-8}$	$2.26X10^{-8}$	$3.22X10^{-8}$

2.3.2 Investigation of domestic cases of clearance to derive the input values of key input parameters

To modify the key input parameters, selected by the sensitivity analysis, domestic cases of clearance were investigated in a way that meets domestic conditions. The Korea Atomic Energy Research Institute (KAERI) had an experience on the clearance of the waste drums that were generated during the clearance of soil and concrete. There are three key processes. First, the KAERI was licensed by the Korea Institute of Nuclear Safety (KINS), and sent all waste drums to a waste collector. Second, general scrap metals and waste drums were mixed, compressed and cut by the waste collector and sent them to a steel mill. Third, these were processed into recyclables, and distributed them in the steel mill so that general consumers can use them in the end [4]. The actual work time, investigated in domestic cases of clearance and the default input values of the assessment code are shown in **Table 6**.

Table 6. Parameters comparison.

Scenario	Work time (hr/yr)		
	Code (Default)	Actual work	Proportion
Scrap cutter	12	126	10
Scrap loader	4	36	9
Scrap truck driver	4	8	2

2.3.3 Deriving the input values of key input parameters

By the aforementioned sensitivity analysis and the investigation of domestic cases of clearance, the actual work time and the assessment code work time were compared. The comparison results were shown that the actual work time increased 10 times for the scrap cutter scenario, 9 times for the scrap loader, and 2 times for the scrap truck driver than the default inputs of the RESRAD-RECYCLE code. Accordingly, it was performed that the default input values of the work time for the scrap cutter, scrap loader and scrap truck driver scenario were multiplied by 10 times, 9 times and 2 times, respectively, to conduct the assessment in this study.

2.4. Subjects of radiation dose assessment

NPPs are divided into the primary system and the secondary system, and since most of the devices and structures of the secondary system are generated as very low-level (VLW) wastes, it seems that most of them will be made a clearance regardless of decontamination during the decommissioning of a NPP. Therefore, to assess the devices and structures in the primary system for the purpose of verifying the possibility of clearance of contaminated wastes, the Boron Recovery Tank (BRT) pipes and pressurizer were selected as the assessment targets in this study.

2.4.1 BRT pipes

BRT pipes are the structures of Boron Recovery System (BRS) included in the primary chemical and volume control system.

2.4.2 Pressurizer

A pressurizer is a cylindrical pressure vessel installed vertically in the hot leg of the nuclear reactor coolant system (RCS), maintaining the operation pressure of the nuclear reactor coolant system and compensating the change of volume of the nuclear RCS during transient.

2.5. Conditions of radiation dose assessment

To assess the possibility of clearance of radioactive metal wastes generated during the decommissioning of a NPP, the computer code was used to assess the worker risk in this study. For the assessment, Decontamination Factor (DF) and input parameters were used as the variables.

2.5.1 Decontamination Factor

In consideration of the high level of radioactivity of the pressurizer, the DF was applied to the assessment. The pressurizer is a device in the primary system of a nuclear power plant. Since it is contaminated by the reactor coolant, it has to be appropriately decontaminated. It was considered that the chemical decontamination method and the physical decontamination method for decontamination of the pressurizer, and the DF for the chemical decontamination method was assumed 1,000 and the DF for the physical decontamination method was assumed 10,000, respectively. The DF of chemical decontamination referenced the flow polishing decontamination method and according to a Japan case, Japan Power Demonstration Reactor (JPDR) used the flow polishing decontamination method to decontaminate the reactor water purification system, and it was found that the DF can be made 200-1600 [5]. The DF of physical decontamination referenced the abrasive-blast decontamination method, and according to ROK studies, it was confirmed that the decontamination factor can be made up to 16,000. In case of physical decontamination, 6-minute, 9-minute, and 12-minute abrasive-blast decontamination were conducted for the radioactively contaminated tube segments of a steam generator (S/G) pulled out of a NPP in ROK and the DF was checked according to the distance. The results of the abrasive-blast decontamination experiment are shown in **Table 7** [6].

Table 7. DF of the abrasive-blast decontamination.

DF	6-minute	9-minute	12-minute
1m	2,399	15,907	7,271
4m	265	4,794	12,107
7m	184	2,145	8,705
10m	127	691	3,592
13m	216	1,110	1,921
16m	287	1,372	8,187
19m	8,235	>16,000	>16,000

2.5.2 Input parameters

In this study, the inhalation rate and ingestion rate among the input parameters in the RESRAD-RECYCLE code were modified according to ICRP 60 to follow the domestic assessment system. The dose conversion factors of inhalation and ingestion, which are specified in ICRP 72, were applied to the worker scenarios, and the 5μm Active Median Aerodynamic Diameter (AMAD) particle size was applied to the AMAD about respiration based on ICRP 68 [7-9]. In this study, as the regulation on the unlimited recycling is unclear in ROK, a total of 25 scenarios for worker and limited recycling, applicable to ROK, were assessed, excluding 16 scenarios for the unlimited recycling (consumer goods, public goods, and reuse). In addition, the input parameters, selected previously, were applied to the assessment.

2.6. Result of assessment

2.6.1 BRT pipes

The result showed that BRT pipes meet the permissible radiation dosage for clearance in Korea. The assessment results are shown in **Table 8**.

Table 8. Assessment result of BRT pipe.

Assessment result (Immediate decommissioning)			
Scenario	Individual Dose (μSv/yr)	Modification of Exposure duration (μSv/yr)	Collective Dose (man·Sv/yr)
Scrap Cutter	$3.97X10^{-2}$	$3.97X10^{-1}$	$1.19X10^{-7}$
Scrap Loader	$1.71X10^{-1}$	$1.54X10^{0}$	$3.43X10^{-7}$
Scrap Truck Driver	$7.54X10^{-1}$	$1.51X10^{0}$	$3.77X10^{-6}$
Scrap Processor	$4.06X10^{-2}$		$1.22X10^{-7}$
Smelter Yard Worker	$5.52X10^{-2}$		$5.22X10^{-7}$
Smelter Loader	$2.06X10^{-1}$		$1.03X10^{-6}$
Furnance Operator	$5.09X10^{-1}$		$1.77X10^{-6}$
Baghouse Processor	$1.31X10^{-1}$		$1.31X10^{-7}$
Refinery Worker	$6.49X10^{-1}$		$1.95X10^{-6}$
Ingot Caster	$6.47X10^{-1}$		$1.29X10^{-6}$
Small Objects Caster	$1.49X10^{0}$		$2.98X10^{-6}$
Slag Worker	$0.00X10^{0}$		$0.00X10^{0}$
Ingot Loader	$4.36X10^{-1}$		$8.73X10^{-7}$
Ingot Truck Driver	$1.93X10^{0}$		$9.67X10^{-6}$
Storage Yard Worker	$7.94X10^{-2}$		$7.94X10^{-7}$
Sheet Maker	$1.10X10^{-1}$		$1.66X10^{-6}$
Coil Maker	$5.43X10^{-1}$		$5.43X10^{-7}$
Sheet Handler	$1.10X10^{-1}$		$2.20X10^{-6}$
Coil Handler	$5.42X10^{-1}$		$2.71X10^{-6}$
Product Loader	$4.36X10^{-1}$		$8.73X10^{-7}$
Product Truck Driver	$1.93X10^{0}$		$9.67X10^{-6}$
Sheet Assembler	$1.10X10^{-1}$		$2.20X10^{-6}$
Warehouse Worker	$2.91X10^{-2}$		$1.45X10^{-7}$
Shield Block	$1.27X10^{0}$		$1.27X10^{-6}$
Radwaste container	$9.41X10^{-2}$		$9.41X10^{-8}$

2.6.2 Pressurizer

The result showed that pressurizer is satisfied with the permissible radiation dosage for clearance in Korea after 23 years in case of applying the decontamination coefficient of 1,000 and after 5 years in case of applying the decontamination coefficient of 10,000. The result values of assessment using the DF 1,000 are shown in **Table 9**, and the result values of the assessment using the DF 10,000 are shown in **Table 10**.

Table 9. Assessment result of Pressurizer (DF 1,000).

Assessment result (Immediate decommissioning)			
Scenario	Individual Dose (μSv/yr)	Modification of Exposure duration (μSv/yr)	Collective Dose (man·Sv/yr)
Scrap Cutter	$5.93X10^{-2}$	$6.34X10^{-1}$	$1.78X10^{-7}$
Scrap Loader	$8.53X10^{-2}$	$8.20X10^{-1}$	$1.71X10^{-7}$
Scrap Truck Driver	$7.50X10^{-2}$	$1.50X10^{-1}$	$3.75X10^{-7}$
Scrap Processor	$6.06X10^{-2}$		$1.82X10^{-7}$
Smelter Yard Worker	$5.50X10^{-1}$		$5.50X10^{-6}$
Smelter Loader	$1.02X10^{-1}$		$5.12X10^{-7}$
Furnance Operator	$3.67X10^{-1}$		$1.10X10^{-6}$
Baghouse Processor	$1.63X10^{-2}$		$1.63X10^{-8}$
Refinery Worker	$4.04X10^{-1}$		$1.21X10^{-6}$
Ingot Caster	$2.01X10^{-1}$		$4.03X10^{-7}$
Small Objects Caster	$9.28X10^{0}$		$1.86X10^{-5}$
Slag Worker	$1.54X10^{-6}$		$1.54X10^{-12}$
Ingot Loader	$1.09X10^{-1}$		$2.17X10^{-7}$
Ingot Truck Driver	$2.41X10^{-1}$		$1.20X10^{-6}$
Storage Yard Worker	$3.95X10^{-1}$		$3.95X10^{-6}$
Sheet Maker	$1.37X10^{-2}$		$2.06X10^{-7}$
Coil Maker	$6.75X10^{-2}$		$6.75X10^{-8}$
Sheet Handler	$1.37X10^{-2}$		$2.74X10^{-7}$
Coil Handler	$5.40X10^{0}$		$2.70X10^{-5}$
Product Loader	$1.09X10^{0}$		$2.17X10^{-6}$
Product Truck Driver	$3.85X10^{-1}$		$1.92X10^{-6}$
Sheet Assembler	$2.74X10^{-1}$		$5.47X10^{-6}$
Warehouse Worker	$2.07X10^{0}$		$3.62X10^{-5}$
Shield Block	$4.51X10^{-2}$		$4.51X10^{-8}$
Radwaste container	$3.34X10^{-3}$		$3.34X10^{-9}$

Table 10. Assessment result of Pressurizer (DF 10,000).

Assessment result (Immediate decommissioning)			
Scenario	Individual Dose (μSv/yr)	Modification of Exposure duration (μSv/yr)	Collective Dose (man·Sv/yr)
Scrap Cutter	$6.34X10^{-2}$	$5.93X10^{-1}$	$1.90X10^{-7}$
Scrap Loader	$9.11X10^{-2}$	$7.68X10^{-1}$	$1.82X10^{-7}$
Scrap Truck Driver	$8.01X10^{-2}$	$1.50X10^{-1}$	$4.01X10^{-7}$
Scrap Processor	$6.48X10^{-2}$		$1.94X10^{-7}$
Smelter Yard Worker	$5.87X10^{-1}$		$5.87X10^{-6}$
Smelter Loader	$1.09X10^{-1}$		$5.47X10^{-7}$
Furnance Operator	$3.92X10^{-1}$		$1.18X10^{-6}$
Baghouse Processor	$1.74X10^{-2}$		$1.74X10^{-8}$
Refinery Worker	$4.31X10^{-1}$		$1.29X10^{-6}$
Ingot Caster	$2.15X10^{-1}$		$4.30X10^{-7}$
Small Objects Caster	$9.91X10^{0}$		$1.98X10^{-5}$
Slag Worker	$7.55X10^{-3}$		$7.55X10^{-9}$
Ingot Loader	$1.16X10^{-1}$		$2.32X10^{-7}$
Ingot Truck Driver	$2.57X10^{-1}$		$1.28X10^{-6}$
Storage Yard Worker	$4.22X10^{-1}$		$4.22X10^{-6}$
Sheet Maker	$1.47X10^{-2}$		$2.20X10^{-7}$
Coil Maker	$7.21X10^{-2}$		$7.21X10^{-8}$
Sheet Handler	$1.46X10^{-2}$		$2.92X10^{-7}$
Coil Handler	$5.76X10^{0}$		$2.88X10^{-5}$
Product Loader	$1.16X10^{0}$		$2.32X10^{-6}$
Product Truck Driver	$4.11X10^{-1}$		$2.05X10^{-6}$
Sheet Assembler	$2.92X10^{-1}$		$5.85X10^{-6}$
Warehouse Worker	$2.21X10^{0}$		$3.86X10^{-5}$
Shield Block	$4.81X10^{-2}$		$4.81X10^{-8}$
Radwaste container	$3.57X10^{-3}$		$3.57X10^{-9}$

3. Conclusion

To assess the possibility of clearance of radioactive metal wastes generated during the decommissioning of a NPP, the RESRAD-RECYCLE computer code was used to assess risks with regard to workers and limited recycling. The assessment targets were the structures of the primary system, i.e. the BRT pipes and the pressurizer and to improve the reliability of the assessment results, the input parameters in the code were modified to meet Korean condition. In addition, in consideration of the level of radioactivity of the pressurizer, the DF was applied to the assessment. The assessment results were shown that the BRT pipes were satisfied with the clearance permissible dose after the permanent shutdown of the NPP, and the pressurizer was satisfied with the clearance permissible dose 23 years later when the DF 1,000 was applied, and 5 years later when the DF 10,000 was applied. It is expected that this study will be helpful to assessment for clearance of decommissioning wastes that will be generated after the actual decommissioning of a NPP in the future.

Acknowledgements

This work was supported by the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and the Ministry of Trade, Industry & Energy (MOTIE) of the Republic of Korea (No. 20141510300310)

References

[1] NSSC, Regulations on the classification of radioactive waste and clearance standards, *Notification 2014-003*, Nuclear Safety and Security Commission, (2014).

[2] ANL/EAD-3, RESRAD-RECYCLE – a computer model for analyzing the radiological doses and risks resulting from the recycling of radioactive scrap metal and the reuse of surface contaminated material and equipment, ANL/EAD-3, (2000).

[3] A.R. Kim, A proposal of the method of assessing the contamination levels of radioactive metal waste and a criteria for reutilizing the waste, Master's thesis, Kyung Hee University (2009).

[4] D.S. Hong, I.S. Gang, Y.Y. Ji, J.S. Son, G.S. Ju, G.G. Gil and U.S. Ryu, A dose assessment of scrap processing worker considering actual working environment during clearance of drum, *Korean Association for Radiation Protection* 3(1) (2011), pp.62-63.

[5] I. Michio, *Decommissioning of the Reactor: for Safe Retirement*, Seoul, (1997), pp.100-101, ISBN 8986978024.

[6] KAERI, *Development of a Technology of Volume Reduction and Clearance for Large Metal Wastes from NPPs*, Korea Atomic Energy Research Institute, (2011).

[7] S.B. Hong, B.J. Lee and U.S. Chung, A study on the clearance lever(draft) for the steel scrap from the KRR-1 & 2 decommissioning, Korean Radioactive Waste Society 2(1) (2004), pp. 61-67.

[8] ICRP, Dose coefficients for intakes of radionuclides by workers, *ICRP Publication 68*, (1994).

[9] ICRP, Age-dependent doses to members of the public from intake of radionuclides: Part 5 compilation of ingestion and inhalation dose coefficients, *ICRP Publication 72*, (1995).