Preliminary Assessment of Potential Risk From Inadvertent Recycling of Disposed Activated Metal Waste and Its Implications

Wang Hyeon Lee, Ki Nam Kwon, and Jae Hak Cheong*
Kyung Hee University, 1732 Deokyoungdaero, Giheung-gu, Yongin, Gyeonggi-do, Korea
*jhcheong@khu.ac.kr

1. Introduction

Not only surface contaminated metal waste but activated metal waste is generated due to neutron activation of metallic structure around reactor core where neutron flux is maintained during the operation of a nuclear power plant. The International Atomic Energy Agency (IAEA) estimates the amount of activated metal waste is to be 650 ton from the decommissioning of a PWR of 900-1300 MWe [1].

Most of the surface contaminated metal waste can be recycled if the clearance acceptance criteria (concentration or dose) can be met with or without surface decontamination. However, much of the activated metal waste that exceeds the clearance level is to be disposed of at a radioactive waste disposal facility due to the difficulty of decontamination of volumetrically activated matrix.

For metal waste disposed of at a radioactive waste disposal facility, it is expected that the radiation effects and its consequences due to normal evolution scenarios and low probability events are not significantly different from other waste streams. However, the potential recycling of metal waste disposed of at a disposal facility cannot be excluded, since the metallic material inadvertently excavated on the ground through human intrusion for the purpose of exploring resources after the period of post-closure institutional control of disposal facilities can be considered as s valuable resources to be recycled.

Therefore, this study intends to evaluate the expected impacts of inadvertent recycling of activated metal waste after surface disposal and analyzed the implications therefrom.

2. Methodology

In this study, three types of radionuclides such as ^{59}Ni, ^{63}Ni and ^{94}Nb which are present in activated metal waste generated from nuclear power plants were selected through literature review [2]. Radionuclides with short half-lives such as ^{60}Co were not taken into account as the residual radioactivity is expected to be insignificant after hundreds of years of the period of post-closure control of the disposal facility.

The radionuclides present in scrap metal are distributed to the three phases of ingot, slag and dust filter at a certain ratio in the smelting process. Table 1 shows the mass partitioning factor (MPF) and element partitioning factor (EPF) of a metal smelting process.

Table 1. Mass and Element partitioning factor of scrap metal

By-product		Ingot	Slag	Dust Filter
MPF		90%	10%	1%
EPF	^{59}Ni	99%	0%	1%
	^{63}Ni	99%	0%	1%
	^{94}Nb	0%	99%	1%

The concentration of elements present in the by-product in the smelting process can be defined by the following equation:

$$C_{i,by-product} = C_{i,scrap} \cdot \frac{EPF_i}{MPF_i} \qquad (1)$$

where, i is the radionuclide, $C_{i,by\text{-}product}$ is the concentration of radionuclide i in the by-product (ingot, slag, and dust filter), and $C_{i,scrap}$ is the concentration of radionuclide i in the scrap.

Therefore, when the scrap metal with initial radioactivity concentration of 1 Bq/g is subject to a

smelting process, the radioactivity concentration of ^{59}Ni and ^{63}Ni in the ingot is 1.1 Bq/g, which is insignificant, but the radioactivity concentration of ^{94}Nb in the slag is 9.9 Bq/g, which causes considerable concentration in the smelting process.

The radiation dose expected from the scenario to recycle activated metal waste can be evaluated using the RESRAD-RECYCLE Version 3.10 computer code. The code was originally developed by ANL to assess the expected radiation dose for workers in the scrap metal or waste aluminum recycling process and the general population using consumer goods and public goods by a total of 41 scenarios.

3. Results and Discussion

Table 2 shows the calculated radiation dose using the RESRAD-RECYCLE computer code when scrap metal of unit radioactivity concentration (1 Bq/g) is recycled after the post-closure institutional control period of 300 years [3].

Table 2. Results of radiation dose calculation

Radio-nuclide	Exposure dose (mSv/y)		
	Before smelting	Ingot recycle after smelting	Slag recycle after smelting
^{59}Ni	3.24×10^{-8}	2.82×10^{-8}	-
^{63}Ni	9.87×10^{-9}	8.78×10^{-9}	-
^{94}Nb	1.69×10^{-4}	-	1.63×10^{-1}

In cases of ^{59}Ni and ^{63}Ni, the workers handling with scrap metal at the smelting facility turns out to receive the highest dose. The radioactivity concentration equivalent to 1 mSv/y for human intrusion dose criterion is very high (i.e. 10^7-10^8 Bq/g), which is much higher compared to the disposal concentration limit (7.4×10^4 and 1.11×10^7 Bq/g, respectively) for the low-level radioactive waste repository. In other words, the potential impact of recycling of metal waste is already covered in the existing disposal safety assessment framework.

However, the radioactivity concentration of ^{94}Nb equivalent to 1 mSv/y was estimated to be 10 Bq/g, which is lower than the disposal concentration limit (i.e. 111 Bq/g). In reviewing the calculation process, the highest radiation dose was calculated in the scenario of slag recycling. The radiation dose prior to the smelting process was calculated to be insignificant, since ^{94}Nb in scrap metal is mostly partitioned to the slag phase in the smelting process.

4. Conclusion

In this study, the potential impacts of inadvertent recycling of low-level activated metal waste disposed at a near-surface disposal facility using the RESRAD-RECYCLE computer code.

In the case of radionuclides such as ^{94}Nb, it was shown that the disposal concentration limit for the low-level radioactive waste repository may not be sufficient enough to warrant the protection of the potential intruders. More detailed studies on the recycling scenarios of activated metal waste disposed at a near surface disposal facility may be needed especially in preparation of decommission of nuclear power plants where large amount of activated metal waste will be generated.

REFERENCES

[1] International Atomic Energy Agency, “Managing Low Radioactivity Material from the Decommissioning of Nuclear Facilities”, IAEA Technical Reports Series No. 462 (2008).

[2] Pacific Northwest Laboratory, “Long-Lived Activation Products in Reactor Materials”, NUREG/CR-3474 (1984).

[3] Enforcement Decree of the Nuclear Safety Act, Article 99(2) (2017).