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Characteristic analysis and optimum management plan of disused sealed radioactive sources in Korea

Juyoul Kim *, Sukhoon Kim, Seunghee Lee

FNC Technology Co., 32F, 13 Heungdeok 1-ro, Giheung-gu, Yongin-si, Gyeonggi-do 16954, Republic of Korea

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ABSTRACT

This study reviewed the current status of disused sealed radioactive source (DSRS) in Korea and analyzed its characteristics according to three factors, i.e., IAEA recommended classification system of radioactive waste based on the half-life of radionuclides, potential risk index based on activity divided by the corresponding radionuclide-specific 'D value' and legal classification scheme of radioactive waste based on the concentration of radionuclides. The optimum management procedure was derived based on above three factors above and applied to DSRS which are currently being stored in the centralized temporary storage facility for the radioisotope (RI) waste operated by Korea Radioactive Waste Agency (KORAD). The results of this study would be used as technical background document to draw up an optimum management plan of DSRS in the near future.

1. Introduction

Currently, most of disused sealed radioactive sources (DSRSs) generated in Korea are stored in the temporary storage facility of Korea Radioactive Waste Agency (KORAD). On July 2015, seven DSRSs (four boxes of ^{63}Ni nuclide) were transferred to the rock cavern type disposal facility in Gyeongju for the first time. KORAD will receive DSRSs and the annual amount of acceptance is expected to be 33 drums on average. Therefore, the future plan on DSRS disposal should be established as soon as possible in accordance with the construction and operation plan of disposal facility.

Since DSRSs have a great variety of characteristics, the domestic disposal environment and source-specific characteristics should be considered for optimizing the disposal method. In this study, the optimum management plan for the disposal of DSRS has been suggested based on the characteristics of DSRS and relevant regulatory requirements.

2. Characteristic Analysis of disused sealed radioactive sources in Korea

The Notice No. 2014-3 of Nuclear Safety and Security Commission (NSSC) categorizes the radioactive waste into five groups; high-level radioactive waste (HLW), intermediate-level radioactive waste (ILW), low-level radioactive waste (LLW), very low-level radioactive waste (VLLW) and exempt waste (EW) (NSSC, 2014a). Radionuclide-specific clearance level of EW for self-disposal and concentration limit of LLW are shown in Tables 1 and 2, respectively. If the concentration of waste is between clearance level in Table 1 and centuple of clearance level, the radioactive waste is classified as VLLW. Also, if the concentration is between one hundred times of clearance level and concentration limit in Table 2, the radioactive waste is classified as LLW. Fig. 1 shows the classification system of radioactive waste in accordance with the Korean regulation.

From 1991 to 2014, 34 radionuclides of DSRS have been generated in various area including industry, hospital, research and education organization. They are as follows:

- 23 radionuclides whose half-lives are lower than 30 years; ^{210}Bi, ^{125}I, ^{124}Sb/Be, ^{192}Ir, ^{75}Se, ^{210}Po, ^{153}Gd, ^{68}Ge, ^{57}Co, ^{109}Cd, ^{134}Cs, ^{22}Na, ^{147}Pm, ^{252}Cf, ^{55}Fe, ^{60}Co, ^{133}Ba, ^{85}Kr, ^{3}H, ^{152}Eu, ^{244}Cm, ^{90}Sr, ^{90}Sr/^{90}Y.
- 9 radionuclides whose half-lives are higher than 30 years; ^{137}Cs, ^{63}Ni, ^{241}Am, ^{241}Am/Be, ^{226}Ra, ^{226}Ra/Be, ^{14}C, ^{235}U, ^{238}U.
- 2 mixed sources including ^{60}Co and ^{90}Sr, respectively.

Among these DSRSs, 7 radionuclides are alpha sources including ^{210}Po, ^{252}Cf, ^{244}Cm, ^{241}Am, ^{226}Ra, ^{235}U, ^{238}U and remaining radionuclides are beta sources. The radionuclides containing Beryllium such as Sb/Be, Am/Be and Ra/Be are neutron sources. Although most of DSRSs are solid form, some DSRS such as ^{85}Kr and ^{3}H exist as gaseous form in the sealed container with unbreakable and

* Corresponding author.
E-mail address: gracemi@fnctech.com (J. Kim).

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Table 1
Radionuclide-specific clearance level of exempt waste (NSSC, 2014a).

Radionuclide	Clearance Level (Bq/g)
I-129	0.01
Na-22, Sc-46, Mn-54, Co-56, Co-60, Zn-65, Nb-94, Ru-106, Ag-110m, Sb-125, Cs-134, Cs-137, Eu-152, Eu-154, Ta-182, Bi-207, Th-229, U-232, Pu-238, Pu-239, Pu-240, Pu-242, Pu-244, Am-241, Am-242m, Am-243, Cm-245, Cm-246, Cm-247, Cm-248, Cf-249, Cf-251, Es-254	0.1
C-14, Na-24, Cl-36, Sc-48, V-48, Mn-52, Fe-59, Co-57, Co-58, Se-75, Br-82, Sr-85, Sr-90, Zr-95, Nb-95, Tc-96, Tc-99, Ru-103, Ag-105, Cd-109, sn-113, Sb-124, Te-123m, Te-132, Cs-136, Ba-140, La-140, Ce-139, Eu-155, Tb-160, Hf-181, Os-185, Ir-190, Ir-192, Tl-204, Bi-206, U-233, Np-237, Pu-236, Cm-243, Cm-244, Cf-248, Cf-250, Cf-252, Cf-254	1
Be-7, F-18, Cl-38, K-43, Ca-47, Mn-51, Mn-52m, Mn-56, Fe-52, Co-55, Co-62m, Ni-65, Zn-69m, Ga-72, As-74, As-76, Sr-91, Sr-92, Zr-93, Zr-97, Nb-93m, Nb-97, Nb-98, Mo-90, Mo-93, Mo-99, Mo-101, Tc-97, Ru-97, Ru-105, Cd-115, In-111, In-114m, sn-125, Sb-122, Te-127m, Te-129m, Te-131m, Te-133, Te-133m, Te-134, I-126, I-130, I-131, I-132, I-133, I-134, I-135, Cs-129, Cs-132, Cs-138, Ba-131, Ce-143, Ce-144, Gd-153, W-181, W-187, Pt-191, Au-198, Hg-203, Tl-200, Tl-202, Pb-203, Po-203, Po-205, Po-207, Ra-225, Pa-230, Pa-233, U-230b, U-236, Np-240, u-241, Cm-242, Es-254m	10
H-3, S-35, K-42, Ca-45, Sc-47, Cr-51, Mn-53, Co-61, Ni-59, Ni-63, Cu-64, Rb-86, Sr-85m, Sr-87m, Y-91, Y-91m, Y-92, Y-93, Tc-97m, Tc-99m, Rh-105, Pd-109, Ag-111, Cd-115m, In-113m, In-115m, Te-129, Te-131, I-123, I-125, Cs-135, Ce-141, Pr-142, Nd-147, Nd-149, Sm-153, Eu-152m, Gd-159, Dy-166, Ho-166, Er-171, Tm-170, Yb-175, Lu-177, re-188, Os-191, Os-193, Ir-194, Pt-197m, Au-199, Hg-197, Hg-197m, Tl-201, Ra-227, U-231, U-237, U-239, U-240, Np-239, Pu-234, Pu-235, Pu-237, Bk-249, Cf-253, Es-253, Fm-255	100
Si-31, P-32, P-33, Fe-55, Co-60m, Zn-69, As-73, As-77, Sr-89, Y-90, Tc-96m, Pd-103, Te-125m, Te-127, Cs-131, Cs-134m, Pr-143, Pm-147, Pm-149, Sm-151, Dy-165, Er-169, Tm-171, W-185, re-186, Os-191m, Pt-193m, Pt-197, At-211, Th-226, Pu-243, Am-242, Cf-246	1000
Co-58m, Ge-71, Rh-103m, Fm-254	10,000

Table 2
Radioactivity Concentration limit for low-level waste (NSSC, 2014a).

Radionuclide	Radioactivity concentration (Bq/g)
H-3, Cs-137	1.11×10^6
C-14	2.22×10^5
Co-60	3.70×10^7
Ni-59, Sr-90	7.40×10^4
Ni-63	1.11×10^7
Nb-94	1.11×10^2
Tc-99	1.11×10^3
I-129	3.70×10^1
Gross-alpha	3.70×10^3

non-corrosive material. The majority of DSRSs have been generated from industrial organizations, and it took about 87.5% in volume. The next is medical institute followed by public, research, educational and military institution in order.

As shown in Fig. 2, the total number of DSRSs was 52,176 over the past 24 years. ^{192}Ir took about 69.7% and its number was 36,382. ^{3}H took about 10.5%, followed by ^{147}Pm (3.9%), ^{241}Am (3.7%), ^{60}Co (3.3%), ^{137}Cs (2.5%), ^{147}Pm (1.7%), ^{85}Kr (1.0%), ^{226}Ra (0.9%), ^{90}Sr (0.7%). In terms of radioactivity, total radioactivity was estimated as 1.514×10^9 Bq as of 2014. ^{137}Cs took the highest portion of radioactivity, which was about 59.3% of total activity. ^{60}Co took 37.5% of total activity followed by ^{241}Am (2.0%), ^{85}Kr (0.6%), ^{241}Am/Be (0.2%), ^{226}Ra (0.1%), ^{63}Ni (0.09%), ^{90}Sr (0.04%), ^{147}Pm (0.04%), ^{244}Cm (0.02%). The total volume of DSRS including the storage container was 6.43×10^4 L, and ^{60}Co took 55.1% followed by ^{137}Cs (16.8%), ^{192}Ir (9.8%), ^{57}Co (4.9%), ^{241}Am/Be (3.6%), ^{85}Kr (2.1%), ^{226}Ra (1.6%), ^{63}Ni (1.5%), ^{241}Am (1.4%), and ^{147}Pm (0.8%). In summary, ^{60}Co, ^{137}Cs, ^{192}Ir, ^{241}Am and ^{241}Am/Be took

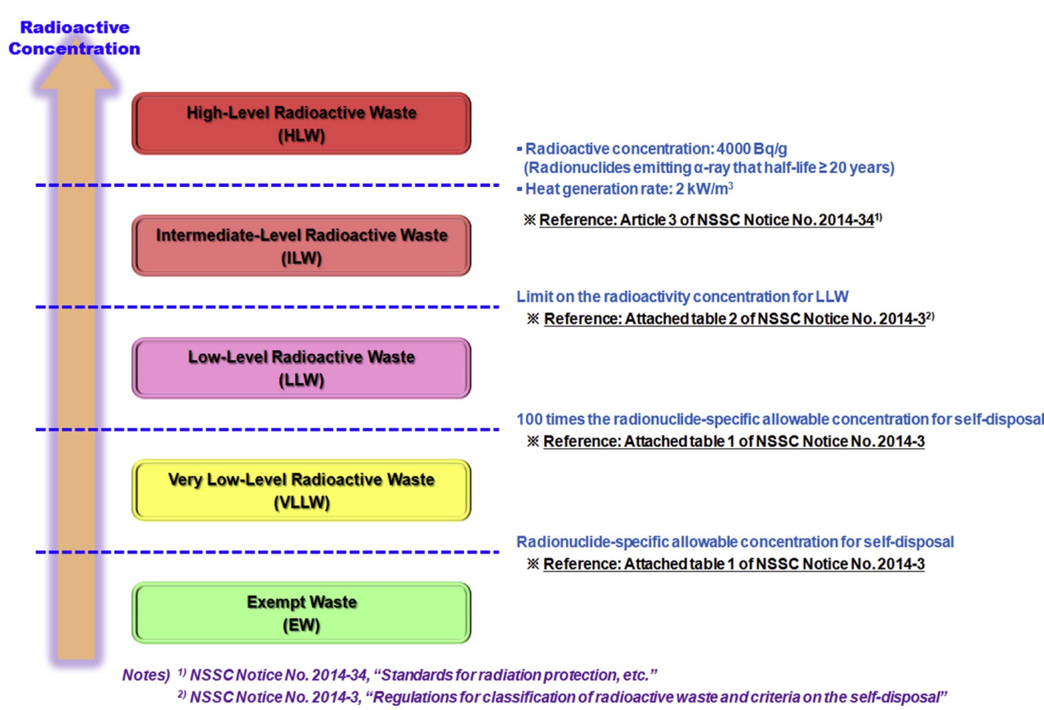

Fig. 1. Classification system of radioactive waste in Korea.