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ISSUES ON EXEMPTION LEVELS FOR PACKAGE SURFACE CONTAMINATION SIMPLY DERIVED FROM IAEA-TECDOC-1449 "RADIOLOGICAL ASPECTS OF NON-FIXED CONTAMINATION OF PACKAGES AND CONVEYANCES"

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ABSTRACT

The present regulation on surface contamination [Bq/cm^2] is determined from a simple radiological model for the most hazardous radionuclides (Pu-239 for α emitters and Sr-90 for β emitters) and its extremely conservative model is applied for all other α and β emitters. In the TECDOC-1449 report published by the International Atomic Energy Agency (IAEA), the effect of radiation from non-fixed contamination on packages is evaluated and the dose conversion coefficients [$(mSv/y)/(Bq/cm^2)$] are calculated for each radionuclide.

In this study, exemption levels for surface contamination are calculated with the dose conversion coefficients in TECDOC-1449. The dose criterion for deriving the exemption level is chosen to be 0.01 mSv/y, to maintain consistency with fundamental concepts adopted by the safety standards committees, namely, the Radiation Safety Standards Committee (RASSC), the Transport Safety Standards Committee (TRANSSC) and the Waste Safety Standards Committee (WASSC).

The result shows that the exemption levels for α emitters such as Pu-239 and Am-241 are extremely low. This is because the resuspension rate from the manual packages and the inhalation scenario in TECDOC-1449 have been set conservatively. For materials containing a mixture of radionuclides, the exemption can be judged on the basis of the satisfaction of the condition Σ D/C < 1, where D represents an actual measurement result and C represents the exemption level. If these extremely low surface contamination exemption levels are adopted for practical use, a small amount of α contamination can lead to a large contribution to the sum in the above condition expression in the case of nuclear power plants that are assumed to have experienced fuel damage.

Moreover, it can be recognized that the result for Co-60 is approximately equal to 0.4 Bq/cm^2, but it is less than 0.8 Bq/cm^2, which is equivalent to the regulation of NRC RG-1.86 and the Nuclear and Industrial Safety Agency (NISA) guideline that specifies the level of no contamination in nuclear power plants in Japan. This is because the working scenario assumed in

TECDOC-1449 is unrealistic, such as the one in which a site worker continually unloads and fixes packages.

In this study, we conclude that the scenarios and parameters assumed in TECDOC-1449 should be more realistic to derive practical and reasonable exemption levels for package surface contamination.

INTRODUCTION

Currently, the regulatory requirements applicable to removable surface contamination are found in the IAEA Regulations for the Safe Transport of Radioactive Material(1). The regulation states that the non-fixed contamination on the external surfaces of any package shall be kept as low as practicable and, under routine conditions of transport, shall not exceed the following limits: (a) 4 Bq/cm^2 for β and γ emitters and low toxicity α emitters, and (b) 0.4 Bq/cm^2 for all other alpha emitters. The regulation also states that the levels of non-fixed contamination on the external and internal surfaces of overpacks, freight containers, tanks and intermediate bulk containers shall not exceed the limits specified above. These requirements are based on a dosimetric model developed by the Fairbairn(2). These limits are derived using a simple model of worker exposure. It considers only the inhalation of airborne contamination and transfer of contamination to human hands under a specified set of exposure scenarios for the most hazardous nuclides (Pu-239 for α emitters and Sr-90 for β emitters), and its extremely conservative model is applied for all other α and β emitters.

It was reported in the International Journal of Transport of Radioactive Material(3) that contamination in excess of the regulatory limits was observed in some flasks and wagons transporting radioactive material. However, no significant radiation exposure to the workers or the public had occurred. It was recognized that issues related to packages and conveyances needed to be reevaluated. The Transport Safety Standards Committee (TRANSSC) recommended at its May 2000 meeting that the IAEA undertake a coordinated research project (CRP) on non-fixed contamination. The objective was to review the scientific basis for the current regulatory limits for surface contamination. During the period since the current contamination limits were derived, there have been a number of changes in radiation protection mainly as a result of the recommendations of the International Commission on Radiological Protection (ICRP). These include changes in the dose coefficients for the inhalation of radionuclides and the annual dose limit for workers. Moreover, much experience has been gained in their use in many types and stages of the transport of radioactive materials. The CRP working groups carried out research on the radiological aspects of radioactive contamination and then IAEA published the TECDOC-1449 “Radiological aspects of non-fixed contamination of packages and conveyances” (4) as the final result of research undertaken during the CRP. In the TECDOC-1449, the dose conversion coefficients [$(mSv/y)/(Bq/cm^2)$] are calculated for each radionuclide.

In this study, exemption levels for package surface contamination are simply derived from the dose conversion coefficients in TECDOC-1449 and its problems in practical use and the exposure scenarios and parameters are examined and discussed.

METHOD

TECDOC-1449 provides data on dose conversion coefficients [(mSv/y)/(Bq/cm^2)] for the surface contamination. In this study, the exemption levels for package surface contamination were derived, dividing dose criterion by the dose conversion coefficients calculated in TECDOC-1449. The dose criterion for deriving exemption levels was chosen to be 0.01 mSv/y, which was the same as the dose criterion of the IAEA Basic Safety Standards (BSS)(5), which specifies the exemption levels for radiation sources, and the IAEA Safety Standards Series No.RS-G-1.7(6), which specifies the concepts of exclusion, exemption, and clearance. Taking into account the results of these two documents, 0.01 mSv/y as the exemption dose criterion has gained the general consensus and it can maintain consistency with fundamental concepts adopted by the safety standards committees, namely, RASSC, TRANSSC and WASSC.

RESULTS

Table 1 shows the dose conversion coefficients for the representative radionuclides and the result of the derived exemption levels for package surface contamination.

The result shows that the exemption levels for α emitters such as Pu-239 and Am-241 are extremely low, such as of the order of 10^{-3} Bq/cm^2. For materials containing a mixture of radionuclides, the exemption can be judged on the basis of the satisfaction of the condition Σ D/C < 1, where D represents an actual measurement result and C represents the exemption level. If these extremely low exemption levels for surface contamination are adopted for practical use, a small amount of α contamination can lead to a large contribution to the sum in the above condition expression in the case of nuclear power plants assumed to have experienced fuel damage.

Moreover, it can be recognized that the result for Co-60 is approximately equal to 0.4 Bq/cm^2, but it is less than 0.8 Bq/cm^2, which is equivalent to the regulation of NRC RG-1.86(7) and the Nuclear and Industrial Safety Agency (NISA) guideline that specifies the level of no contamination in nuclear power plants in Japan.

ANALYSIS

CONSERVATIVE RESUSPENSION RATE AND INHALATION SCENARIO

As shown in **Table 1**, the results of exemption levels for α emitters are extremely low, because the resuspension rate from the surface of the manual packages and the inhalation scenario have been set conservatively in TECDOC-1449.

In TECDOC-1449, an indoor calculation of the air concentration has been produced. The models utilize the resuspension rate method of calculation. The indoor air concentration model relies on the assumption that the resuspended activity will distribute evenly over the entire volume of a room and that this occurs instantaneously.

The effective dose related to the inhalation in TECDOC-1449 is given by

$$E = \frac{RR \times A \times A_C}{V \times f_{ex}} \times contain \times frac \times T \times INH \times R_{10},$$

where
E = effective dose (Sv/y)
RR = resuspension rate (h^{-1})
A = the surface area of the package from which resuspension occurs (m^2)
A_c = the activity per unit area of package (Bq/m^2)
V = room volume (m^3)
f_{ex} = the air exchange rate of the room (h^{-1})
contain = containment factor, included for packages that are covered, which has default values of 1 % for covered packages and 1 for uncovered packages (-)
frac = respirable fraction, scenario dependent, but is conservatively assumed to be 1 for all assessed scenarios (-)
T = exposure time, scenario dependent (h/y)
INH = breathing rate (m^3/h)
R_{10} = inhalation dose coefficient (Sv/Bq).

The chosen resuspension rate in TECDOC-1449 was 10^{-4} [h^{-1}] for all radionuclides, except tritium. The value chosen for tritium was 10^{-1} [h^{-1}] by taking into account evaporation from the surface at a much higher rate. Relevant publications in this respect are NUREG(8) and the report of experimental work in Japan(9). In both publications, a resuspension rate of 10^{-4} [h^{-1}] is at the upper end of the data given in the result. Even in the case of tritium, the resuspension rate was 10^{-4} [h^{-1}] in the experimental work in Japan. Furthermore, the working group of TECDOC-1449 noted that adopting a value of 10^{-4}[h^{-1}] is a conservative approach by quoting their publications. It can be appropriate to use such conservative parameters to derive the surface contamination limit for safety transportation, but for the practical and reasonable exemption levels for package surface contamination, the resuspension rate should be more realistic in correspondence with the experimental result.

In addition to the conservative resuspension rate, the inhalation scenario itself was also conservative in TECDOC-1449. In the basic model of CRP, the packages were divided into four types, small manually handled packages (SM), small remotely handled packages (SR), large remotely handled packages (LR), and irradiated nuclear fuel flasks (FF). The most dominant exposure scenario of the α emitters was the inhalation of the radionuclides resuspended from the surface of small manually handled packages in a small van that has no separate compartment. Therefore, the driver is modeled to directly inhale the radionuclides resuspended from the surface of the package. In a realistic situation, however, the van used for the safe transportation of radioactive materials often has a firm separation between the driver space and the carrying space and there can be less possibility of inhaling the radionuclides directly.

It can be appropriate to use the conservative inhalation scenario as well as the conservative parameter to derive the surface contamination limits for safe transportation, but for the practical and reasonable exemption levels for package surface contamination, the inhalation scenario should be more realistic.

CONSERVATIVE EXTERNAL EXPOSURE SCENARIO

As shown in **Table 1**, the result of exemption levels for Co-60 is approximately equal to 0.4 Bq/cm^2 but it is less than 0.8 Bq/cm^2, which is equivalent to the regulation of NRC RG-1.86 and the NISA guideline that specifies the level of no contamination in nuclear power plants. This is because the most dominant exposure scenario of Co-60 was external exposure and its scenario assumed in TECDOC-1449 is unrealistic and extremely conservative, such as the one in which a site worker continues to unload and fix packages.

The effective dose related to the external exposure in TECDOC-1449 is given by

$$E = A_c \times T \times DE / 1000,$$

where
E=effective dose (mSv/y)
A_c=activity concentration on package (1 Bq/cm^2, scaled to Bq/m^2)
T=exposure time (h/y)
DE=effective dose equivalent rate in rotational geometry (mSv/h)

Each of the four types of packages was modeled as simple geometries and the effective dose equivalent rate was calculated using MicroShield[10]. In the case of the small remotely handled package, it was modeled as a set of cylindrical objects whose diameter was 0.6 m and height was 0.9 m, the objects were piled and the area of exposure became a rectangle (1.8 $\times$ 4.2 m^2) as shown in **Figure 1.**

In the external exposure scenario in TECDOC-1449, a single site worker is modeled to continually unload packages from one conveyance, which includes performing dose rate and contamination measurements, unfixing, fastening and lifting, and also modeled to continually load packages on other conveyances, which includes fixing, performing dose rate and contamination measurements at conveyances, and carrying out the contamination measurement and placarding of conveyances. Through such continuous work, the single site worker is continually irradiated 1 m away from the large rectangular radioactive object.

In a realistic situation, there can be several workers around the radioactive objects and there can be less possibility that a single site worker continually works near the radioactive object where radioactivity is distributed over the entire rectangle area. It can be appropriate to use the conservative external exposure scenario to derive the surface contamination limits for safe transportation, but for practical and reasonable exemption levels for package surface contamination, the exposure scenario should be more realistic.

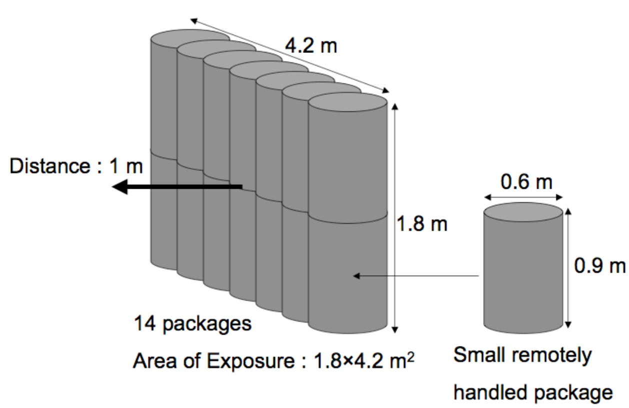

Figure 1. Conservative external exposure geometries of small remotely handled packages

Table 1. Dose conversion coefficients in TECDOC-1449 and derived exemption levels for package surface contamination

Radionuclides	Dose conversion coefficients [(mSv/y)/(Bq/cm^2)]	Exemption levels [Bq/cm^2]
H-3	8.5×10^{-4}	1.2×10^{1}
C-14	1.7×10^{-4}	6.0×10^{1}
Cl-36	1.8×10^{-4}	1.3×10^{1}
Ca-41	6.7×10^{-5}	1.5×10^{2}
Mn-54	8.5×10^{-3}	1.2
Fe-55	9.1×10^{-5}	1.1×10^{2}
Co-60	2.5×10^{-2}	4.1×10^{-1}
Ni-59	2.3×10^{-5}	4.3×10^{2}
Ni-63	5.5×10^{-5}	1.8×10^{2}
Zr-65	6.5×10^{-3}	1.5
Sr-90	9.5×10^{-3}	1.1
Nb-94	1.7×10^{-2}	6.1×10^{-1}
Tc-99	1.8×10^{-4}	5.5×10^{1}
I-129	2.5×10^{-2}	4.0×10^{-1}
Cs-134	2.0×10^{-2}	5.0×10^{-1}
Cs-137	8.9×10^{-3}	1.1
Eu-152	1.3×10^{-2}	8.0×10^{-1}
Eu-154	1.5×10^{-2}	6.7×10^{-1}
Pu-239	3.1	3.2×10^{-3}
Am-241	2.6	3.8×10^{-3}

CONCLUSIONS

Using the dose conversion coefficients calculated in TECDOC-1449, we have examined simply derived exemption levels for package surface contamination. This study shows that the exemption levels for α emitters and Co-60 are extremely low and not practical values in comparison with the current regulatory requirements. This is because the inhalation scenario, including the resuspension rate, and external exposure scenario considered in TECDOC-1449 are extremely conservative.

In this study, we conclude that the scenarios and parameters assumed in TECDOC-1449 should be more realistic to derive practical and reasonable exemption levels for package surface contamination.

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