Preliminary Studies on Reuse of Particle Accelerator Rooms After Decommissioning

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1. Introduction

Unlike diagnostic radiation generators using photons, the particle accelerator for radiation therapy and isotope production emits high-energy particle radiation. The structures and equipment in the accelerator room are to be activated by energetic particles, and the residents in the room will be exposed by the residual radioactivity present in the activated structures even after dismantling or relocation of the accelerator. As the number of particle accelerators reaching closer to the design-lifetime increases, verification of the acceptable residual radioactivity of the former accelerator rooms is becoming an important issue. Case studies on actual dismantling of particle accelerators have been reported in USA and a preliminary study on decommissioning planning criteria for a cyclotron was reported in Korea [1-3].

The site release criteria for major nuclear facilities after decommissioning are set forth in the NSSC Notice No. 2016-33, however particle generators are excluded from the scope of the Notice. Furthermore, no specific studies on the methodology to calculate the Derived Concentration Guideline Levels (DCGLs) for structures activated by particle accelerators have been reported.

In this study, we proposed three methodologies to derive DCGLs for the rooms to be remained after decommissioning of particle accelerators based upon residual radioactivity in terms of surface and volumetric contamination (i.e. Bq/m^2 or Bq/m^3).

2. Method & Calculation

2.1 Method I : DCGLs in Surface Radioactivity

In NUREG-1757 (Consolidated Decommissioning Guidance), derived site release criteria for buildings and soils are given in terms of surface activity and volumetric activity, respectively. Since the particle accelerator rooms belong to a building, a method to derive DCGLs in terms of residual surface activity can be assumed for a first.

In this study, RESRAD-BUILD code was used to calculate expected dose from remaining room surfaces (i.e. four walls, one ceiling, and one floor) and to derive DCGLs. However, simply assuming the volumetrically activated indoor structures as surface-contaminated surfaces may induce limitations of not taking into consideration of the exposure to be caused by the activated volume sources.

2.2 Method II : DCGLs in Volumetric Radioactivity

DCGLs in terms of volumetric activity may represent the radiological conditions of the remaining actual room structures activated by energetic particles very well. Method II is based on the assumption that the room structures of a certain depth are three-dimensionally activated. In this study, DCGLs were derived assuming homogeneous residual radioactivity in all surrounding indoor concrete structures by use of RESRAD-BUILD code.

It is expected that the surface region of structure is much highly activated than the innermost part of the structure. Therefore, DCGLs derived by Method II may be too much conservative if all structures are assumed to be activated at the same level of activity concentration. Due to the potential presence of various activation products in concrete, however, determination of DCGLs may be more complex than simple direct application of the available pre-set Default Screening Values (DSVs) in NUREG-1757.

2.3 Method III : Balanced DCGLs

Another approach to calculate dual DCGLs for external and internal exposures separately was reported in USA [1-2]. The rationale for this approach relies on the fact that volumetrically activated inner concrete layers mainly contribute to the external exposure pathway because the activation products are not available for intake. However, removable contamination layers on the surface of concrete structures may dominate the internal exposure pathway. Accordingly, they proposed the DCGL for external exposure (i.e. from activated concrete volume) in dose rate (μSv/h) and the DCGL for internal exposure (i.e. from removable surface contamination) in surface activity concentration (Bq/m^2) as shown in Table 1 and as below [1-2]:

$$\mathrm{DCGL_{external}} = 0.24\ \mathrm{mSv/y} \div 2360\ \mathrm{h/y} = 0.1\ \mu\mathrm{Sv/h}$$

In this study, the concept of "Balanced DCGLs" were proposed for which the site release dose constraint is proportionated to the separate DCGLs for external and internal exposure pathways, respectively, as appropriate in consideration of the actual conditions of the residual rooms as:

$$\mathrm{DC_{total}} = \mathrm{DC_{external}} + \mathrm{DC_{internal}}$$

$DC_{external} = \alpha DC_{total}$
$DC_{internal} = (1-\alpha) DC_{total}$
where, DC_{total} is the overall dose constraint, $DC_{external}$ is the DC for external pathway, $DC_{internal}$ is the DC for internal pathway, and α is the fraction appropriately balanced ($\alpha \le 1$).

Table 1. Removable activity contribution to total dose

Nuclide	Annual internal dose			Removable activity equivalent to 1 mrem/y
	mrem per 0.1 Bq/m^2			
	inhalation	ingestion	total	Bq/m^2
^{60}Co	2.92E-03	1.75E-04	3.08E-04	3.24E+02
^{134}Cs	5.59E-04	4.32E-04	9.94E-04	1.01E+03
^{152}Eu	3.07E-03	4.38E-05	3.11E-03	3.22E+02
^{154}Eu	3.92E-03	6.35E-05	3.98E-03	2.50E+02

2.4 Assumptions to derive DCGLs

Based on the above three methods, RESRAD-BUILD code is used to calculate DCGLs for a hypothetical room geometry shown in Fig. 1. All surrounding structures are assumed to be ordinary concrete. The radionuclides formed from activation are assumed as ^{60}Co, ^{134}Cs, ^{152}Eu, and ^{154}Eu [1-2]. The location of the receptor is in the center of the room. The criteria for reuse of the site is assumed to be 0.1 mSv/y. Additionally, other input data such as ingestion rate, breathing rate, deposition velocity etc. are determined by referring to industrial practices and/or proper values for the situation.

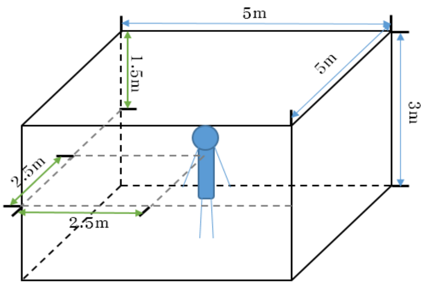

Fig. 1. Geometry in RESRAD-BUILD code.

In case of unit surface/volumetric activity, surface contamination is assumed to be 1 Bq/m^2 and volumetric activity concentration is assumed to be 1 Bq/g. The wall thickness was assumed to be 150 cm when estimating the DCGLs for volumetric activation situation. Occupancy factor is derived from the working time of 2000 hours per year.

3. Results

DCGLs derived by use of the three methods are shown in Table 2. In proportionating the contributions from internal and external pathways, α is set to 96%. That is 4% of the total dose constraint was assumed to be from internal exposure and 96% from external exposure. The value of α can be determined as appropriate taking into account the field conditions.

Table 2. Calculated DCGLs per each methodology proposed

		DCGLs			
		^{60}Co	^{134}Cs	^{152}Eu	^{154}Eu
Method I : Surface, Total (Bq/m^2)		1.52 E+04	2.47 E+04	2.80 E+04	2.59 E+04
Method II : Volumetric, Total (Bq/g)		5.98 E-02	1.09 E-01	1.30 E-01	1.21 E-01
Method III: Volumetric, Total	Surface, Internal (Bq/m^2)	6.82 E+02	6.27 E+02	5.11 E+02	4.17 E+02
	Dose rate, External (mSv/y)	0.096			

4. Conclusion

Three approaches to calculate DCGLs for the particle accelerator rooms remained after decommissioning were proposed. The Method 1 is best applicable for the non-activated surface contamination areas. Therefore, it is not suitable for the application to activated structures and devices. Method II, solely based on the volumetric contamination DCGLs, is most direct forward to derive values in using RESRAD-BUILD code. This method can be applied assuming that all the concrete structures are evenly activated to the depth. However, this method cannot reflect the fact that the extent of actually activated regions are not uniform in practice. Method III is very flexible because total dose constrain is to be proportionated into dual DCGLs for external and internal exposures. However, this method is practically applicable only when the derived are dose rate from proportionated external dose constraint can be discernable from the background radiation level of the remaining room areas. If the official site release criteria for the radiation facilities including particle accelerators are promulgated, applicable DCGLs for the dominantly activated room structures can be derived by use of either of Method II or Method III. The relative feasibilities of the two methods may vary depending on the actual conditions of the remained rooms such as the characteristics of the extent of activation, radioactivity measurement and survey techniques to apply, and the level of site release criteria, and so forth.

REFERENCE

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[3] Rina Woo, et al., Studies on the Introduction of Decommission Planning Criteria through Case Analyses of Relocation of Domestic Cyclotron and Overseas Decommissioning, Journal of Radiation Protection, 38(2), 2013.