Development of screening criteria for the activated components of LINAC for medical use

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1. Introduction

As of May 2020, about 230 linear accelerators are in use in Korea for medical purpose, and the replacement cycle is getting shorter due to the expansion of demand and the introduction of the latest treatment technologies. In such a situation, the activation problems of discarded linear accelerators and structures is being important as a regulatory issue, and a preemptive study on this is required. In the case of disposing of radio-activated components or facilities, the licensees are responsible for the analysis of the radioactivity concentration for each radionuclide. If that happens, it costs a lot of money and time for the licensees. In addition, if even the minimum screening criteria are not provided, it is difficult to limit the scope of the analysis, and this can act as a burden on not only the licensees but also the regulatory body, so it can be seen as one of the important roles of the regulatory body.

2. Method

In order to prepare the screening criteria, a hypothesis expected to be used as a criterion was determined, and whether the hypothesis was valid was verified according to the following procedure.

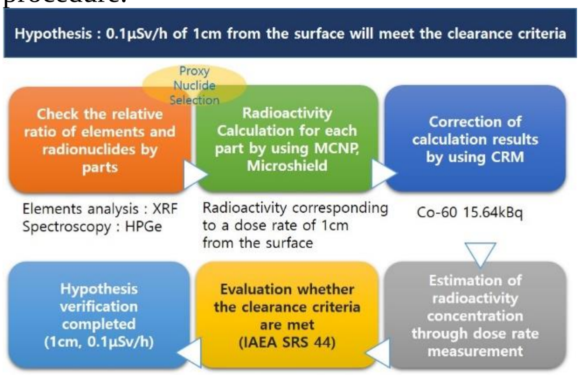

Fig. 1. Procedure for verification of hypothesis

2.1 Proxy nuclide

Table 1 shows the nuclides that can be generated by radiation in consideration of the material of the linear accelerator component. Co-60 was selected as a proxy nuclide to be used to determine whether or not to satisfy the clearance criteria from a measurement point of view by comprehensively considering the half-life of the nuclide, radiation emission, production yield, and radiological hazard. In lead and aluminum, Co-60 is not produced as a major produced nuclide, but since their reference nuclides generate gamma rays with high emission rates, it can be expected that evaluation by considering them as gamma rays from Co-60 will still show conservative results. In addition, in the case of tungsten, gamma-ray emitting nuclides are not produced, but since the nuclides emit characteristic X-rays after the electron capture reaction, it is expected that there will be no difficulty in detecting photons. In order to select a proxy nuclide in this way, activation must mainly occur near the surface, gamma rays or X-rays must be sufficiently detected, and there must be no alpha emitting nuclides. In this study, these conditions can be considered to be satisfied.

Table 1. Exposure pathways for conditional clearance of activated accelerator [1]

Material	Nuclides generated	Reference nuclides
Lead	Tl-204, Sb-124	Sb-124
Copper	Fe-55, Co-57, Co-60	Co-60
Aluminum	Na-22	Na-22
Iron	Mn-54, Fe-55, Co-57, Co-60	Co-60, Mn-54

2.2 Selection of measurement instrument and Dose assessment

Although it is possible to measure the radioactivity concentration using HPGe detectors, in this case, there are too many factors to be considered, and the result value is distorted due to the uncertainty of the factor itself. In addition, the clearance concentration of Co-60 is 0.1Bq/g, which requires too much effort, cost and time to measure up to this value. Therefore, rather than focusing on accurately measuring an object that is difficult to measure, the approach was based on the dose rate using GM counter, and the radioactivity and radioactivity concentration corresponding to the dose rate was evaluated by using computer simulation with MCNPX and Microshield. Since the radiation dose rate has a characteristic that does not depend largely on the type of measuring device, it can be easily measured by any licensee, and has the advantage of being easy for regulatory body to judge. In addition, a sufficiently conservative assumption was made so that the result does not underestimate the risk, and a CRM is used for verification of the computer simulation. Based on the estimated activity or activity concentration, it is possible to evaluate whether the clearance criteria, 10μSv/y are met. If such a measurement method is recommended, it is expected that any licensees can easily perform the measurement and judge whether the components are activated or not.

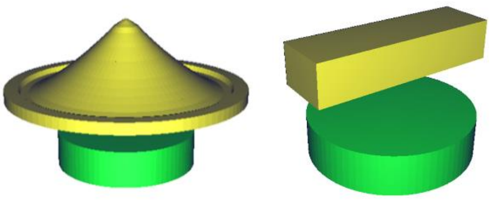

Fig. 2. Radioactivity calculation corresponding to a dose rate of 1cm from the surface of flattening filter and target (MCNPX)

2.3 Scenarios for clearance of induced components

In medical linear accelerators, the activated components are all metals, and they are limited to being reused or recycled by metal related facilities. In addition, due to the characteristics of metals, internal exposure occurs only when reprocessed in a foundry, so external exposure is considered for residents or workers in facilities other than foundry. Therefore, it can be determined whether or not it is possible to be regarded as a non-radioactive parts by limiting the scenarios to WF, WO, RF, RH, and RP among the above IAEA scenarios [2].

Since Co-60 was selected as the proxy nuclide, the radioactivity concentration that satisfies the clearance criteria for each scenario (Actual: 10μSv/y, Low probability: 1mSv/y) based on Co-60 is as follows.

Table 2. Conditional clearance level for metal recycling scenarios for Co-60

Scenario	Exposure pathways	Concentration(Bq/g)	
		Actual	Low Prob.
WF	External exposure	2.1	4.9
	Inhalation	2.8E5	6.5E5
	Ingestion	1.6E3	2.9E3
WO	External exposure	1.1	4.9
RH	External exposure	0.03	0.3
RP	External exposure	0.5	4.0
	Inhalation	8.2E4	4.1E4
	Ingestion	82	4.1E2

3. Result

The radioactivity concentration and total radioactivity were calculated for targets and flattening filters that are expected to have relatively high radioactivity concentration due to the highly activated and light weight, and the result value was corrected based on the measurement result using CRM. According to the results of computational simulation, in the case of the target, the radioactivity concentration was evaluated as 3.23Bq/g and the total radioactivity was evaluated as 217Bq, and the filter was evaluated as 1.07Bq/g and 250Bq. If this value is multiplied by the correction factor 3 derived through CRM, the final result can be predicted as 9.69Bq/g, 651Bq for targets and 3.21Bq/g, 750Bq for filters. Although the radioactivity concentration exceeds the concentration for clearance of Co-60, it is easy to predict that the total radioactivity is within 1% of the exempted quantity, and the resulting exposure dose is less than 10μSv/y.

4. Conclusion

As described above, it was confirmed that there is a limitation in accurately measuring radioactivity for each nuclide for components having various geometries and materials. Therefore, this study proposes a method of selecting proxy nuclides and estimating the radioactivity and concentration of proxy nuclides based on the dose rate and the derived reference level is 0.1μSv/h at a distance of 1 cm from the surface. This proposal is an example of conditional clearance discussed in the IAEA, and will be limitedly applied only to linear accelerators for medical treatment that are not many in use and have completed understanding what kind of components are.

Based on the results of this study, it is expected that it will be a way to ensure sufficient safety while making the regulatory decision on the disposal of radioactive parts more efficiently.

REFERENCES

[1] Commission on Radiological Protection, "Clearance of Accelerators and the removal of accelerator parts from radiation protection areas" (2009).
[2] IAEA, "Derivation of activity concentration values for exclusion, exemption and clearance" (2005)