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Study on Reliability Improvement of Inventory Calculation of Concrete in Cyclotron Facility

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1. Introduction

Accelerators are generally housed in concrete structures for the radiation shielding. The concrete shields are irradiated by radiations and activated during the operation. The increase of radionuclide concentrations causes problems in decommissioning and waste management. Accordingly, concentrations of radio-nuclides must be evaluated and characterized for the decommissioning purpose.

Cyclotron of HDX corporation installed at Severance hospital in Sinchon was operated for 11 years to produce Fluorodeoxyglucose (^{18}F-FDG), radiopharma-ceutical, used in Positron Emission Tomography (PET). The ^{18}F was produced from water ($H_2{}^{18}O$, 95% enriched) irradiated by proton beam of 18 MeV at 35μA. In order to move the cyclotron overseas, the facility was planned to be decommissioned [1].

The residual radioactivities according to the depth of the concrete wall around the cyclotron were evaluated by three methods, in-situ measurement, sample analysis, and calculation using computational codes. The radioactivities obtained by in-situ measurement and sample analysis shows good agreement. In contrast, the calculated values estimated by computational methods were significantly different. Consequently, study on reliability improvement of the computation was carried out.

2. Methods and Results

The residual radioactivities according to the depth of the concrete structures were calculated by using MCNP[2] and FISPACT[3] code in this research. The radioactivities evaluated by computation significantly depend on the input parameters such as primary radiation source, composition of the construction materials, concentration of impurities, operation histories, etc. However, information of each parameter are usually recorded poorly in accelerator facilities [4]. Additionally, it is difficult to improve the reliability of the computation results since the effects of each parameter are unclear. The effect of each variable on radioactivities were verified and the reliability of computation results were improved.

The effect of the way of describing radiation source in simulation was verified primarily. The cyclotron irradiated the proton beam on the enriched water. The production rate of neutron from the reaction between proton beam and water was calculated about 6.29E-3 neutrons/proton. The efficiency of simulation is low when begin with the proton beam due to the low production rate of neutrons. The neutron source term evaluation was performed to describe neutron beam and apply as primary radiation sources in the simulation.

2.1 Neutron source term evaluation

In order to evaluate neutron source term, thickness of the water target was specified primarily. The thickness of the target which produce maximum number of neutrons is required due to the low production rate. The energy deposition according to the thickness was calculated using MCNP code for the thickness selection for maximum neutron production rate as shown in Fig.1. The 0.41 cm of thickness was chosen for the target.

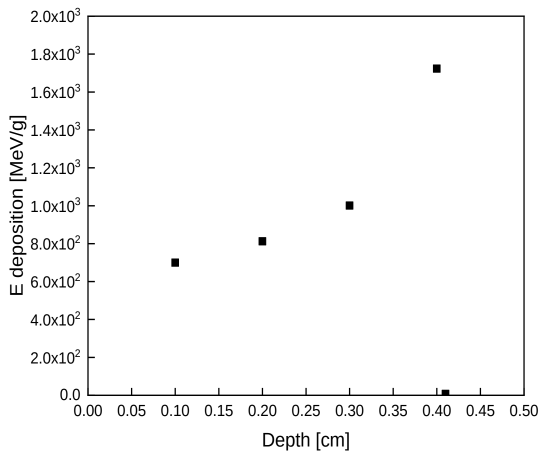

Fig.1 Energy deposition of proton inside water target

The neutron source term was evaluated by measuring neutron spectrum at the surface of the sphere. The neutron source term was described into 176 energy groups in log scale from 0.1eV to 18 MeV. In order to take into account direction of the neutron beam, the angle groups were divided into 19 angle groups. The evaluated neutron source term is illustrated in Fig.2.

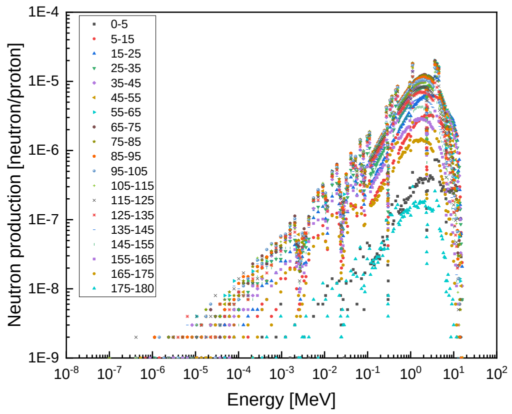

Fig.2 Evaluated neutron source term

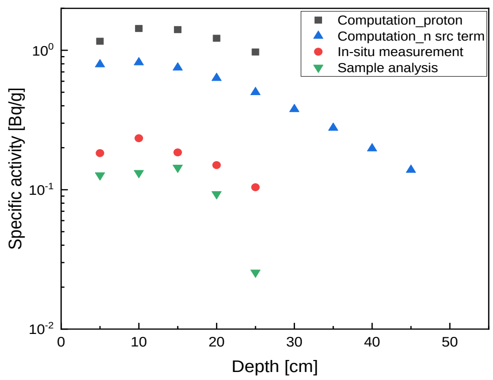

Fig.3 Depth distribution of Co60 inside concrete wall

2.2 Radioactivity calculation

The depth distribution of the residual radioactivity was predicted by using MCNP and FISPACT code. The computations were performed by using two radiation sources to identify the effect of the neutron source term application. In each computation, proton beam and evaluated neutron source term was used as a primary radiation source. The evaluated neutron source term was used as a primary radiation source instead of proton beam in the simulation. The neutron source was generated inside the water target. The specific composition of concrete was adopted from NCRP 144 ordinary concrete. The concentrations of impurities, Co, Cs, and Eu, are assumed due to the lack of the information. The operation history also assumed to operate the cyclotron 2 hours a day for 11 years. However, it was assumed that 11th of an original power and continuous operation. The depth distribution of the residual radioactivity was evaluated up to 45 cm in different positions. One of the computation results of depth distribution for Co60 is shown in Fig.3.

3. Conclusions

The depth distributions of Co60 was calculated by computational codes. The depth distributions were evaluated by two methods. A normal method begins the simulation with the proton beam. The suggested method uses the evaluated neutron source term instead of proton beam. The computed values were compared with the in-situ measurement and sample analysis. The depth distributions of Co60 obtained by in-situ measurement and sample analysis shows relatively good agreement. The computed values were quite different with the values obtained by in-situ measurement and sample analysis. The distribution calculated using evaluated neutron source term shows better result than using proton beam. However, the results still show difference with the measure and sampled values. The differences expected to result from the composition of the concrete, concentration of the impurities, operation histories, etc. Such parameters were mostly assumed in the simulation. The exact values of the parameters would be examined and updated in further simulations and the effects of the parameters would be proved following studies.

Acknowledgement

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