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Analysis of the Residual Radiation Field with Beam Losses from the Proton Accelerator Facility of the PEFP in Korea

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1. Introduction

The Proton Engineering Frontier Project (PEFP) is aimed at building a proton linear accelerator facility with 100 MeV – 20 mA. Presently, a 20 MeV proton accelerator beam line is being assembled and a full beam line of 100 MeV acceleration equipments has been designed. The beam utilizations are possible for a 20/100 MeV proton beam in the PEFP. While the accelerator is being operated, workers must remain outside the accelerator tunnel building. And only after a shut-down, the workers enter the inside of the accelerator tunnel building. Therefore the workers are exposed to the residual radiation field after a shut-down. In this study, the residual radiation field after a shut-down was analyzed to decide on the operational conditions and to reduce the exposure for workers.[1]

2. Calculations

2.1 Methods

The source of a residual radiation field is generally the γ-ray from activation products. Activation products are produced from reactions between the materials in the accelerator tunnel building and protons/neutrons losses during an operation. The materials producing activation products are air, cooling water, and various equipments etc.[2] Therefore a proton beam loss and the secondary neutron spectrum in the accelerator tunnel building should be. In this study, an accelerator tunnel building modeling was performed by using the MCNPX code. The radiation field and productions of the radio-nuclides during an operation were evaluated by using the MCNPX and PHITS codes.

2.2 Evaluation of the Radiation Source Term

The proton beam loss mechanism for the PEFP was analyzed. And the proton and neutron spectra were evaluated in the accelerator tunnel building. Because these radiation source terms were evaluated for each component of the accelerator beam line, 22 radiation source files were produced.[3]

2.3 Evaluation of the Activation Products

Radio-nuclides produced in air with a protons and neutron are ^{3}H, ^{7}Be, ^{11}Be, ^{10}C, ^{11}C, ^{14}C, ^{15}C, ^{13}N, ^{16}N, ^{14}O ^{15}O, ^{37}Ar, and ^{41}Ar. ^{3}H are mainly in the cooling water. And the radio-nuclides from Cu are dominant in various equipments. In this study, all of these radio-nuclides were taken account. The activity of the radio-nuclide produced from an operation during 8 hours is calculated and the required decay time was evaluated. The MCNPX and PHITS codes were used in these calculations.

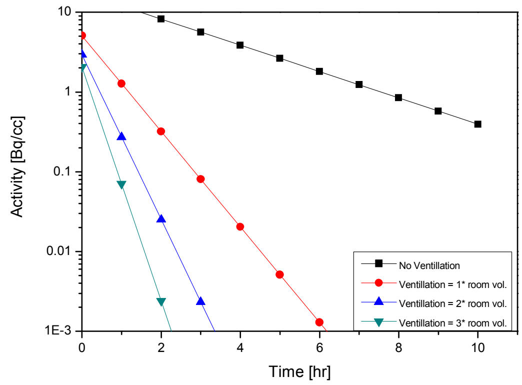

Figure 1. The activities of ^{41}Ar in the air of the accelerator tunnel building

2.4 Evaluation of the Activation Products in the accelerator chain

The proton from beam losses and secondary neutrons were taken account in the evaluation of the activation products in the accelerator chain. Productions of the all radio-nuclides from the SUS-304, STPA21, copper, and steel were calculated by using PHITS code. And assuming 8 hour operation, the concentrations of the radio-nuclides were evaluated. Finally, decays of the evaluated radio-nuclides were calculated.

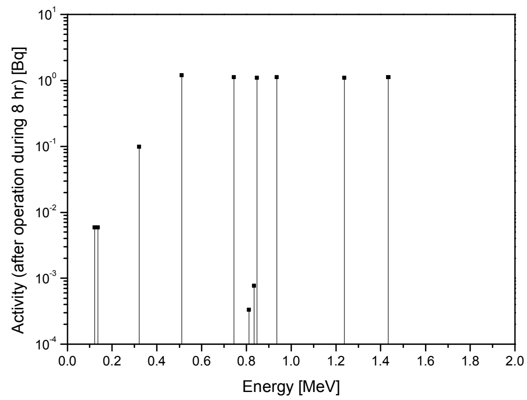

Figure 2. The γ-ray spectrum from the radio-nuclides in the DTL

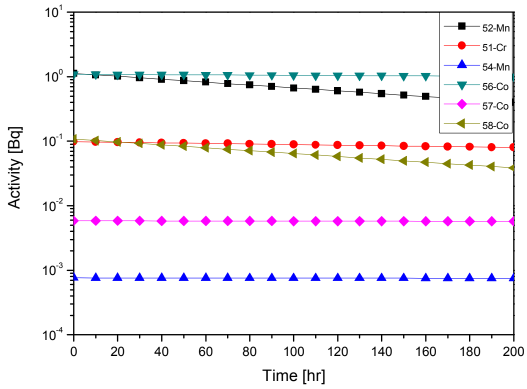

Figure 3. The activities of the radio-nuclides in the DTL after shut-down

Decays of the radio-nuclides in the DTL were evaluated. The effective dose due to γ-ray from the radio-nuclides in the DTL is very low, 0.001817 uSv/hr. Because these radio-nuclides have long half-lives of few hundreds of days, activities decrease very slowly after cooling time of few hundreds of hours.

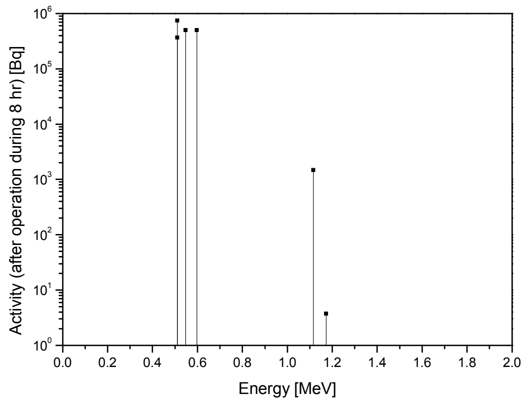

Figure 4. The γ-ray spectrum from the radio-nuclides in the beam dump

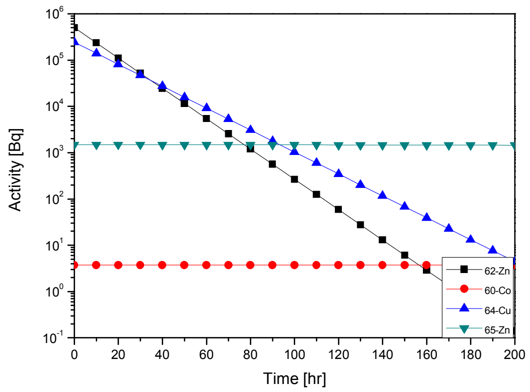

Figure 5. The activities of the radio-nuclides in the beam dump after shut-down

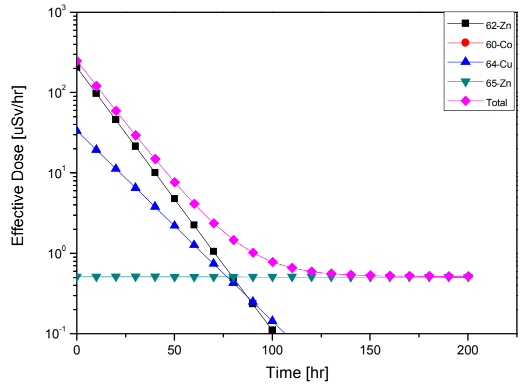

Figure 6. The effective dose due to γ-ray from the radio-nuclides in the beam dump after shut-down

3. Conclusion

The characteristics of the residual radiation field from PEFP are as follows. Without ventilations, the concentration of the ^{41}Ar is not decreased under the limit, 0.05 Bq/cc. The concentrations of the radio-nuclides produced in the accelerator chain are very low. The concentrations of the radio-nuclides produced in the beam dump are higher than limits. Therefore, ventilations for ^{41}Ar and shields for the beam dump should be taken in account for 20 MeV accelerator chain of the PEFP when the beam losses are more than 1 W/m which was assumed in this study.

REFERENCES

[1] IAEA, Radiological Safety Aspects of the Operation of Proton Accelerators, International Atomic Energy Agency, Technical Reports Series No.238, 1988.
[2] Lauriston S. Taylof, et. al., Radiation Protection Design Guidelines for 0.1-100 MeV Particle Accelerator Facilities, Recommendations of the National Council on Radiation Protection and Measurements, 1977.
[3] C.W. Lee, Y.U. Lee, Y.S. Cho, Calculation of Radiation Field for KOMAC with 20 MeV Acceleration Beam Line, Proceedings on Symposium of the 2005 Korea Nuclear Society, 2005.