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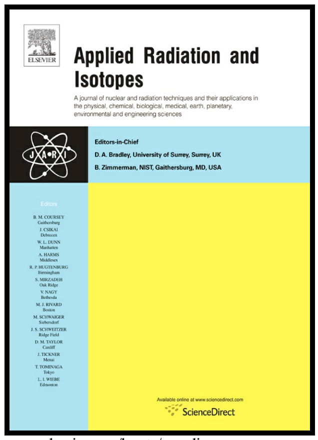

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Abstract

A Proton Accelerator based Boron Neutron Capture Therapy (A-BNCT) facility is under development in Korea. Neutron beams for treatment are produced from a beryllium (Be) target and an 8 mA, 10 MeV proton beam. The purpose of the research is a radiation shielding analysis and an activation analysis for the facility design satisfying the radiation safety requirements as well as obtaining an operating license for the radiation facility according to a domestic nuclear commissioning procedure. The radiation shielding analysis was performed using the MCNPX computational particle transport code. The radiation source terms in the facility were evaluated and utilized in the shielding calculations. The minimum concrete thickness satisfying the designated dose rate of 5μSv/hr for the worker's area and 0.25μSv/hr for the public area were estimated and applied to the design. For an assessment of the radiation safety inside the facility, the dose rates were evaluated at several positions, such as behind the shielding door, around the primary barriers near the radiation sources, and in the penetrations of the ducts. The dose rate distribution was mapped for verification of the radiation safety for the entire facility. An activation analysis was carried out for the concrete walls, air, target assembly, beryllium target, and cooling water using FISPACT-2010 code. Concentrations of the activation products and dose rate induced by the radionuclides after shutdown were evaluated for the purpose of safe operation of the facility. The results were reviewed with the radiation safety regulations in Korea. As a result, it was proved that the final facility design satisfies the safety requirements.

Keyworld: Boron neutron capture therapy, Proton accelerator, Radiation shielding analysis, Activation analysis, Monte Carlo simulation

1. Introduction

Boron Neutron Capture Therapy (BNCT) is a noninvasive therapy for treating malignant tumors, particularly for brain tumors and recurrent head and neck cancers. The sequence for killing tumor cells is as follows. The tumor region is accumulated through ^{10}B (Boron) injected with tumor localizing medicine. ^{10}B is stable and effectively absorbs thermal neutrons with a large absorption cross section of about 3800 b. The tumor cells concentrated with ^{10}B are irradiated using a neutron beam, and produce alpha particles through a $^{10}B(n,\alpha)^{7}Li$ reaction. Consequently, the alpha particles locally destroy the tumor cells by losing their energies [1].

The proton accelerator based BNCT (A-BNCT) facility is under development in Korea for commercialization and a new technology of cancer therapy. A construction drawing of the basement floor is illustrated in Fig. 1.1. The size of the facility is 35 m wide and 30 m long and 5.5 m high. The facility is mainly composed with three treatment rooms, an accelerator room in the basement floor. The ordinary concrete was used as a construction material as well as the shielding material. It is also applied for the materials for the shielding door. The specific composition of ordinary concrete was adopted from ANSI-ANS-6_4-1977 [2]. There are ducts for the air ventilation between the treatment rooms and accelerator room allowing air to flow through the four rooms. The proton beam is produced in the ion-source and transported to the Radio Frequency Quadrupole (RFQ) by an injector with 45 keV. Then, the proton beam is accelerated at up to 3 MeV in RFQ, 7 MeV in Drift Tube Linac-1 (DTL-1), and 10 MeV in DTL-2. Finally, the proton beam has 10 MeV of maximum energy, 8 mA of average beam current, and 80 kW of beam power. The proton beam is irradiated into the beryllium (Be) target inside the target assembly through the beam transport line, and fully stopped inside the target.

The purpose of this study is a performing radiation shielding analysis and an activation analysis for the facility design satisfying the radiation safety requirements and obtaining an operating license for the radiation facility through the domestic nuclear commissioning procedure. A shielding analysis is carried out by evaluating the radiation source term, designing the shield structure, and estimating the exposure. The shielding analysis was performed using the computational particle transport code. The MCNPX 2.7.0 [3] transport code and ENDF/B-VII.1 [4] and JENDL-HE [5] nuclear data library were used for particle transport and nuclear reaction for protons, neutrons, and gamma-rays of up to 10 MeV. Computational codes and a nuclear data library for each particle and reaction are summarized in Table 1.1. The dose rate was calculated with a flux-to-dose conversion factor in ICRP-116 [6].

The activation analysis was performed for the safe operation of the facility after the shutdown. An evaluation of the