Disturbance from Am-241 Photons of the Cellular Dose by Am-241 Alpha Emissions: Am-241 as an alternative source of alpha particles to radon daughters

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1. Introduction

It is known that people are exposed at some mSv to natural radiation, including cosmic rays, terrestrial radiation, and radiations from airborne and oceanic radioactive materials and also food and commercial products. Among them, radon exposure makes the most significant contributor to annual dose (UNSCEAR, 2000) [1]. The Radiation Bioengineering Laboratory (RadBio Lab) at Seoul National University (SNU) has built an Am-241 alpha particle irradiator for study of cellular responses to radiation from radon daughters.

The radon daughters of concern that cause internal exposure from inhalation of radon-contaminated air are Po-218, Po-214 and Po-210. In their alpha decay schemes, the yields of photon emissions are negligible. Unfortunately, Am-241, the source of alpha irradiator in RadBio Lab, emits photons at every alpha decay while transforming to Np-237 of long half-life [2]. Employing Am-241 as the source simulating radon daughters, therefore, requires that photon emissions from Am-241 be specified in term of dose contribution. In this study, Monte Carlo calculations have been made to characterize dose contributions of Am-241 photon emissions.

2. Materials & Methods

2.1 RadBio Lab alpha particle irradiator

The alpha irradiator in RadBio Lab (see Figure 1) has been designed especially for *in vitro* cell experiments. The irradiator housing was made of a stainless steel tube of 470 mm in height and 180 mm in diameter. It has a window for fitting in a cell culture dish, which then is exposed to Am-241 emissions from the bottom. The housing was required to have inner and outer pressures balanced to avoid deformation of cell culture dish. Helium was the choice of gas filling the housing, which was also good for minimum energy loss of alpha particles until reaching the cell targets from emission. Helium atmosphere of high purity was maintained by continuous gas flow through the housing.

The irradiator is equipped with a source of disk shape with 9.5 mm in diameter and 104 to 231 μm in thickness. Am-241, the source radioactive isotope of the irradiator, decays by emitting alpha particles at energies of up to 5.6 MeV with half-life of 432 years. Three Am-241 sources (AFR-241 series, Eckert & Ziegler, USA) of 1, 10 and 100 μCi were purchased for controlling dose rate in an efficient way.

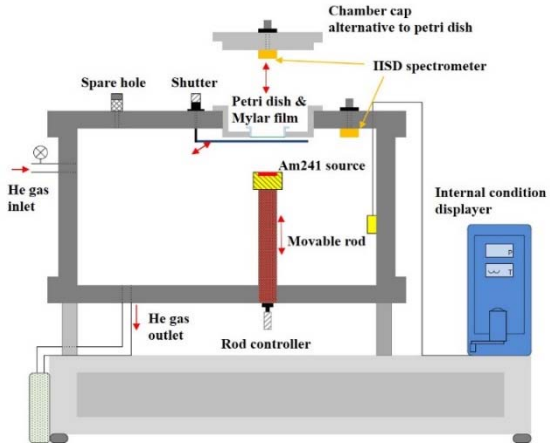

Fig. 1. A sketch of the alpha particle irradiator in RadBio Lab at SNU.

2.2 Photon emissions in alpha decay of Am-241

An Am-241 decays to Np-237 emitting one alpha particle of energy ranging from 5.4 to 5.6 MeV (> 99%), as compared to alpha emissions of 5.3, 6.0 and 7.7 MeV from radon daughters. Each alpha particle emission, except in the decay of Am-241 to the ground energy state of Np-237, may most probably be followed by photon emissions (see Figure 2). The typical gamma emissions carry energies of 26, 33, 43, 60 and 99 keV and the emission yields are 0.024, 0.0013, 0.00073, 0.36 and 0.00020, respectively. In overall, taking into account the alpha decay yields, 60 keV gamma-ray emission is dominant with an emission yield of 0.36. Note that X-ray of 14 keV in mean energy is also emitted via internal conversion at an emission yield of 0.369 [2].

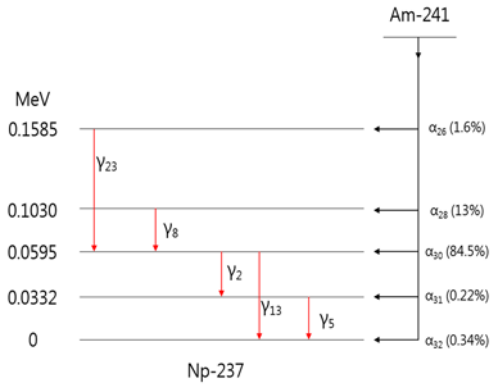

Fig. 2. A decay scheme of Am-241 to Np-237.

2.3 Monte Carlo dose estimation for photons

The average photon dose rate at the cell layer was calculated by using the Monte Carlo code package MCNP5, which enables one to simulate transport of neutrons, photons and electrons in medium and to define three dimensional geometries in an arbitrary way [3]. Dose estimation was performed for photons at six energies of 14, 26, 33, 43, 60 and 99 keV. Calculation was made for a varying source-to-sample distance (SSD) from 5 to 30 mm.

Adherent cells of main interest in the coming studies form a mono-layer of cells during culture. Hence, target cell was configured by a cell nucleus surrounded by cytoplasm, attached to the bottom of cell culture dish. A 5 μm-thick monolayer of water medium was taken to simulate the body of an individual cell. The dish for cell culture is going to be the one with Mylar bottom to minimize the energy loss of alpha particles on the way toward a target cell. In simulating photon transport through the dish bottom, however, a regular plastic of petri dish was used for the medium.

3. Results

Estimates of dose rate due to photon emissions from Am-241 are summarized in Figure 3. Total dose rate by photon emissions at different energies from Am-241 are 24, 13, 7.6, 4.9, 3.4 and 2.4 μGy/min at source-to-sample distances of 5, 10, 15 20, 25 and 30 mm, respectively. Nearly 80 percent of the total dose was attributed to 14 keV X-rays, which correspond to the highest values of LET and emission yield among the photon emissions. Estimates of dose rate attributing to alpha emissions from Am-241 were available from another on-going study [4] with the alpha irradiator in RadBio Lab, which employed the AASI (Advanced Alpha-spectrometric SImulation) code [5] for dose calculation.

The ratio of dose by photon emissions from Am-241 to that by alpha emissions ranges from 6.03×10^{-6} at 5 mm SSD to 8.02×10^{-6} at 25 mm SSD, implying that the photons disturb cellular dose by negligible degrees leaving alpha particles as the major contributor of cellular dose.

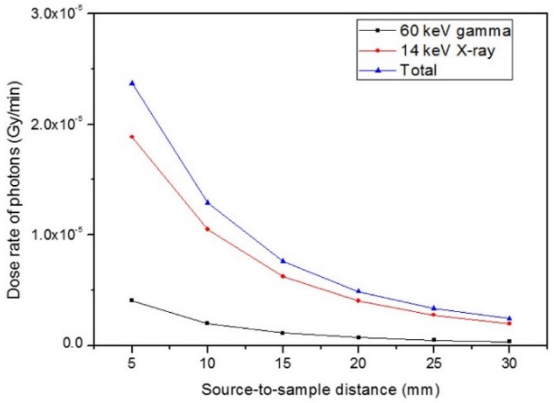

Fig. 3. Dose rates at the cell layer on petri dish by photon emissions from Am-241 for different source-to-sample distances

4. Conclusions

This study confirms that disturbance from Am-241 photon emissions of the cellular dose by Am-241 alpha emissions is negligible. Dose contamination fraction from photon emissions was 8.02×10^{-6} at 25 mm SSD at maximum. Also, note that LET in tissue-equivalent medium varies within about 20% for alpha particles at energies over 5 MeV (http://physics.nist.gov). We are convinced that Am-241 source can be employed as an alternative to radon daughters in performing study on cellular response to alpha particles from radon daughters, on condition that the LET difference among alpha emissions from Am-241 and radon daughters is calibrated in a proper way.

REFERENCES

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