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Estimation of photoneutron intensities around radiotherapy linear accelerator 23-MV photon beam

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HIGHLIGHTS

- Fast neutron relative intensities around a high-energy (23 MV) linac was studied.
- CR-39 nuclear track detectors were used to study the fast neutron variations.
- Neutron fluence was decreased by increasing the distance from isocenter.
- Photoneutron intensities and distributions at isocenter level were also determined.

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ABSTRACT

CR-39 solid-state nuclear track detectors (SSNTDs) were used to study the variations of fast neutron relative intensities around a high-energy (23 MV) linear accelerator (Varian 21EX) photon beam. The variations were determined on the patient plane at 0, 50, 100, 150 and 200 cm from the isocenter of the photon beam. In addition, photoneutron intensities and distributions at isocenter level with field size of $40 \times 40\ cm^2$ at Source Axis Distance (SAD) = 100 cm around 23 MV photon beam were also determined. The results showed that the photoneutron intensities decreased rapidly by increasing the distance from the center of the x-ray beam towards the periphery, for the open fields.

1. Introduction

Radiotherapy represents the most widely spread technique to control and treat cancer. To increase the treatment efficiency, high-energy linear accelerators (linacs) are used (Khan Faiz, 2010). Linacs have several advantages including lower skin dose and higher dose rate at deep sighted tumors (Al-Jarallah et al., 2000). In most radiotherapy facilities, dual-energy linacs with high-photon beams ≥ 10 MV are used for radiotherapy. However, at energies more than 8 MV, photonuclear reactions produce neutron contamination around the therapeutic beam, which may induce secondary malignancies (Hashemi et al., 2007).

These new linacs have the capacity to produce photoneutrons in the target, flattening filters and collimating devices if operated at energies above 10 MeV (Ongaro et al., 2000). Neutrons are produced mainly by (γ, n) reaction when high-energy photons (energy greater than 8 MeV) interact with high Z materials of the linear accelerator head, such as, $^{180}W(\gamma, n)^{179}W$, $^{182}W(\gamma, n)^{181}W$, $^{184}W(\gamma, n)^{183}W$ and $^{186}W(\gamma, n)^{185}W$, on a tungsten target. Other photonuclear reactions in the accelerator and in the materials of the treatment room are also possible and can have wide range of energies, but all are fast neutrons (Al-Othmany et al., 2010; Vega-Carrillo et al., 2010). When the photon energies ≥ 15 MV, the component of the produced neutron in treatment rooms is significant (Ongaro et al., 2000).

SSNTDs have been used by many researchers for direct fast neutron detection or indirect detection for thermal neutrons with the application of a converter on the plastic detector (Mameli et al., 2008; Al-Ghamdi et al., 2008; García et al., 2005). Moreover, CR-39 SSNTDs have been successfully applied for the fast and thermal neutron relative intensity measurements in prompt gamma ray neutron activation analysis (Al-Jarallah et al., 2000). CR-39 is a polycarbonate plastic comprising ($C_{12}H_{18}O_7$), it is made by polymerization of diethyleneglycol bis allylcarbonate (ADC) in presence of diisopropyl peroxydicarbonate. Both NCRP Report 79 (National Council on Radiation Protection and Measurement, 1984) and McGinley's research (McGinley et al., 2000) and others described a method to determine the total neutron fluence ($n\ cm^{-2}$) per unit x-ray dose at isocenter level produced by several different

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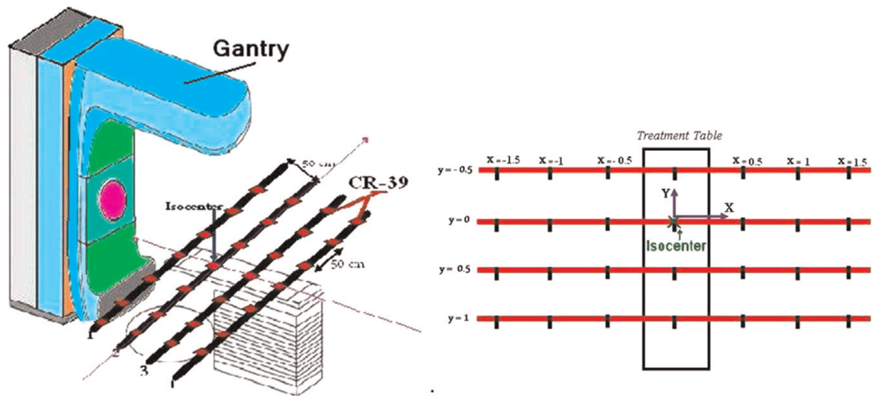

Fig. 1. The location of CR-39 in experimental arrangement around a radiotherapy linear accelerator at isocenter level.

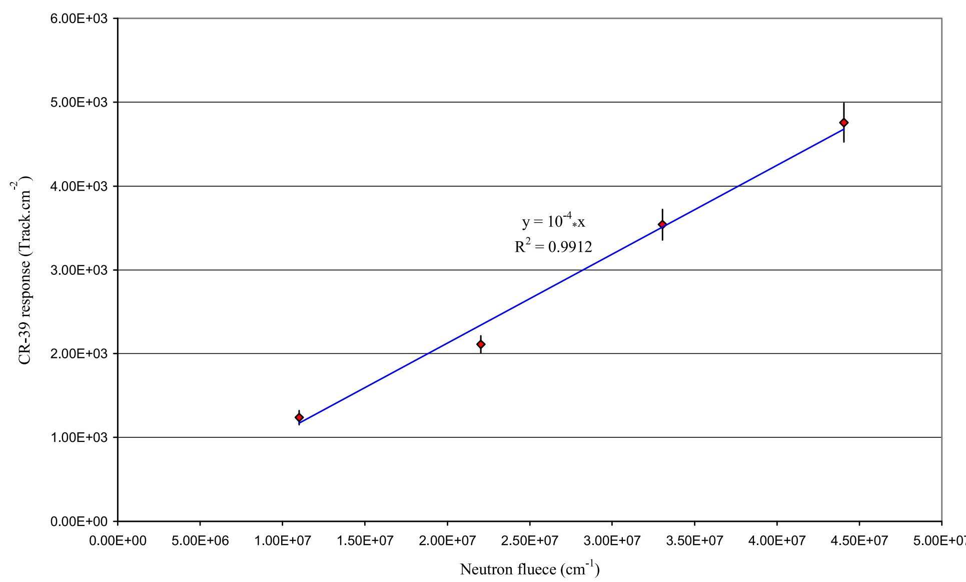

Fig. 2. Calibration of CR-39 detectors.

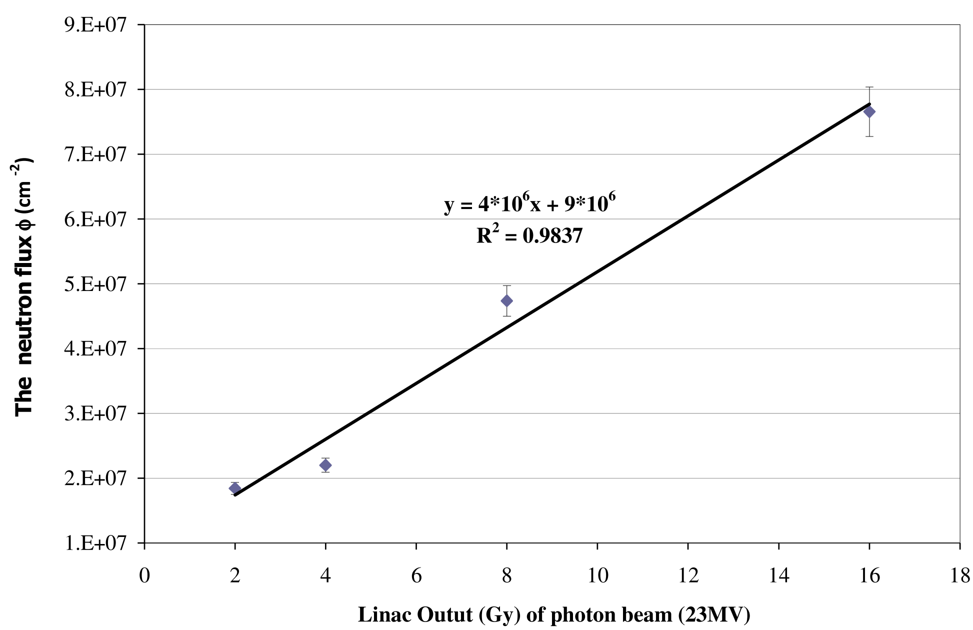

Fig. 3. The relationship between the neutron flux ϕ (cm^{-2}) and linac output (Gy) of photon beam 23 MV.