Journal of Radiation and Nuclear Applications
An International Journal

http://dx.doi.org/10.18576/jrna/050106

Effect of High Photon Energy Spectra on Induced-Photo-Neutron Dosimetry using NTDs

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Received: 21 Feb. 2019, Revised: 22 Mar. 2019, Accepted: 24 Mar. 2019.
Published online: 1 Jan. 2020.

Abstract: In the current study, the induced-photo-neutrons resulting from high energy x-ray photons of medical linear accelerator were measured by CR-39 nuclear track detectors (NTDs). Also, the converter (BN1) of active thin layer of 40 μm in thickness of natural boron was used. It was manufactured by coated natural boron on polyester substrate of about 100 μm in thick. The converter (BN1) screen slide films were used in order to measure the thermal neutron dose through the (n-α) reaction. Moreover, CR-39 NTDs was designed to measure both fast neutron doses through the (n-p), in exposing directly, and thermal neutron doses with converter, respectively. High Photons energy spectra from Elekta medical linear accelerator of 18 MV were used. Results of this work achieved that the measurements of thermal neutron dose relatively smaller than that of the fast neutron dose in case of direct exposure. On the other hand, the ratio of fast to that of thermal is less than that of direct exposure in the case of measurements on phantom and upon the use of build-up Perspex sheets. The validity of using NTDs in the field of photo-neutron detections was carried out and the evaluation of radioecology was concerned.

Keywords: Photo-neutrons – high energy photons – dosimetry - NTDs.

1 Introduction

Nuclear Track Detectors (NTDs) is being method used in widespread fields of radiation sciences and technological applications. NTDs are oftentimes used in radon dosimetry and many other applications such as thermal and fast neutron detections, ^{238}U and ^{232}Th determination in rock samples and spectroscopic applications of charged particles and heavy ion identifications [1-6]. Recently there is a wide expanding use of medical linear accelerators (LINACs) in controlling and treating tumor diseases. LINACs proved to be a vital tool in radiotherapy, as the high energy electrons and photons are very effective in treating deep tumors such as cervical and prostate tumors. However, there is always an undesired contamination of neutrons accompanying the treatment with high energy photons to patients. Photo neutrons are mainly produced from photo-nuclear interactions of hard gamma or x-ray with target, field flattening filters and beam collimators of the LINAC. These photo-neutrons constitute an extra unwanted dose to patients. For this reason excessive work for the accurate measurement of photo-neutrons is very important. During the last decade some of the radiation protection concepts have been changed through the ICRU and ICRP, which lead to the fact that most of the neutron dosimeters are far from ideal, meaning that it needed further research work [7-11].

The famous fast neutron detector CR-39 can register thermal neutron through nuclear reaction in an external converter placed on it. The most common reaction is 10B (n, α) Li. The thermal neutrons induced charged particles have the ability to produce tracks at the CR-39 [12-16].

The aim of this work is measuring the wide energy spectrum of induced thermal and fast photo neutrons by NTDs.

2 Experimental Work

2.1 Materials

The NTDs used were CR-39. CR-39 Sheets of (TASTRACK, supplied by Bristol U.K.) which are a molecular formula of ($C_{12}H_{18}O_7$) with a density of 1.3 g/cm^3 and a thickness of 300 μm which were cut into pieces with an area of 2.0 × 2.0 cm^2 were used. Also, the converter

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(BN1) was manufactured by (Kodak Pathe' Company, France) with thin layer of 40 μm in thickness of natural boron were used, which is coated on polyester substrate of about 100 μm in thick. The converter screen slide films were put in contact with CR-39 NTDs to cover a part of the detector used; the other part of the detector samples were directly exposed to a target in order to register fast neutrons.

2.2 Track Etching and Counting System

Each parts of CR-39 detector, once a time, was etched at optimum conditions which are 6 hr. at 6.25 N NaOH at 70 ºC. Track counting was performed by an automatic image analyzer system [3-4, 15].

2.3 Irradiation setup

Medical linear accelerator manufactured by Elekta was used to deliver dose of 18 MV high energy photons to the detectors. NTDs CR-39 sheets are exposed to doses (2-4-6-8-10) by high energy x-ray from 18 MV Linac at SSD 100 cm and field size 20 x20 cm^2.
Three steps have been performed:

I-First the detectors exposed directly on patient table.

II-Second the detectors placed on chest slab phantom.

III-Third the detectors are placed on chest phantom and covered by 3cm Perspex as a buildup thickness.

3 Results and Discussion

3.1 Thermal Neutron Dosimetry

It is well known that the induced fast neutrons will be registered in CR-39 due to the (n-P) reaction with hydrogen atoms of the detector ,while thermal neutrons will be registered on CR-39 due to the (n-α) reaction with the boron atoms constituting the coating layer of natural boron on polyester surface. So the CR-39 detector is registering both fast and thermal neutrons. Figure 1 represents the variation of alpha track density with x-ray photon doses for the three setup steps. The figure shows that the lowest values of track density are occurred at (on patient table) the first setup which reflects that the induced photo-neutrons are mainly fast neutrons.

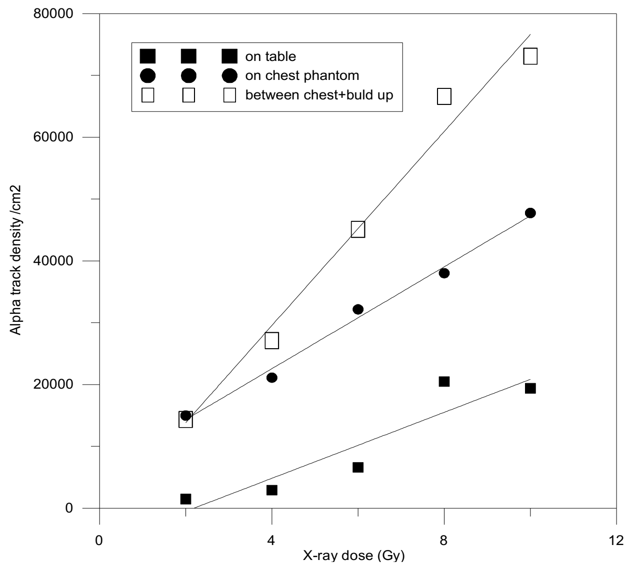

Fig.1: Variation of alpha track density with x-ray doses.

From the track density of alpha particles and by the aid of efficiency factor, the thermal neutron flounce was calculated and represented in Figure 2.

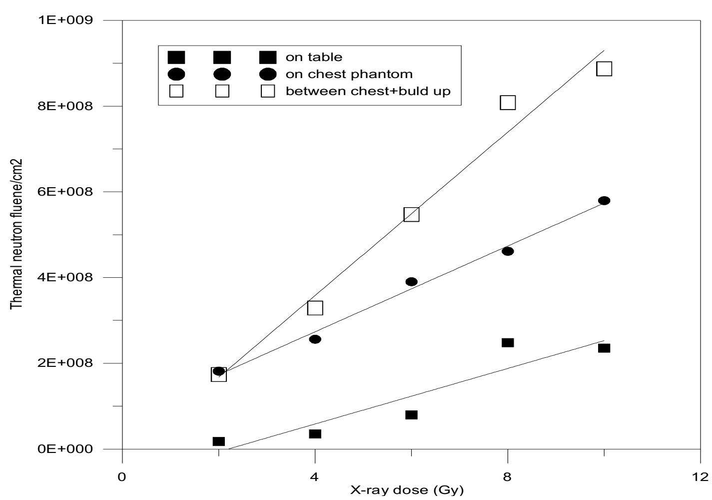

Fig.2: Thermal neutron fluence as a function of x-ray dose.

From the fluence-dose conversion factor, the thermal neutron dose was calculated [13-14] and illustrated in Figure 3.

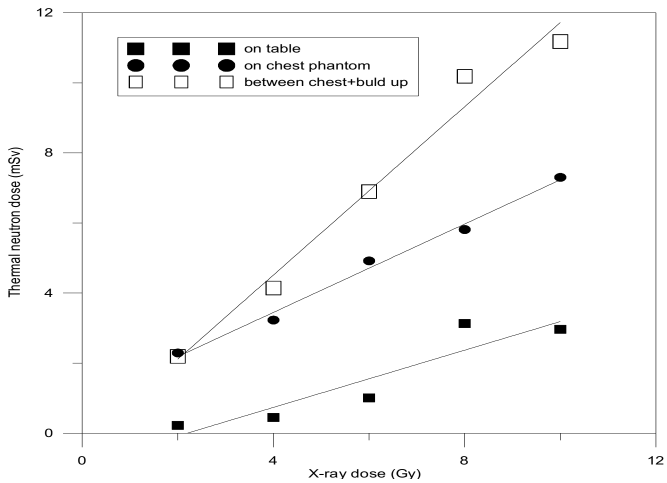

Fig.3: Thermal neutron dose with different x-ray doses.

3.2 Fast neutron dosimetry

Fast neutrons were registered by CR-39 through n-p reaction using image analyzer system. There are a remarkable difference between tracks due to protons and that due to alpha particles. Figure 4 shows the variation of proton tracks with different doses of x-rays. It is obvious from Fig. 4 that the first setup shows the least proton track density.

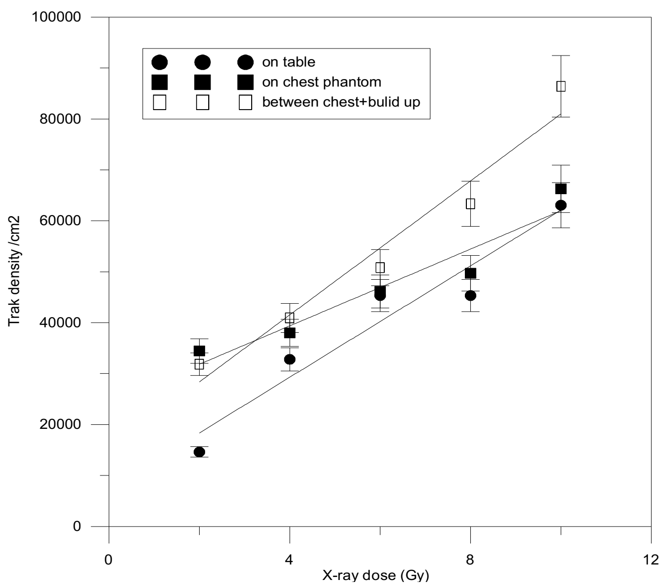

Fig. 4: proton track density with x-ray doses.

Neutron fluence is calculated using the measured proton track density, then the relation between x-ray doses and neutron fluence is presented in Figure 5.

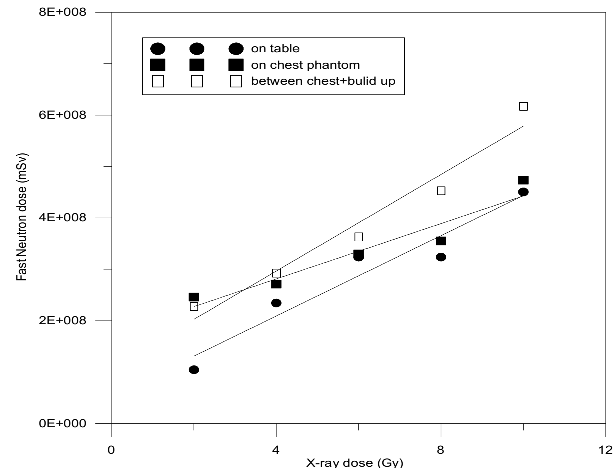

Fig. 5: Fast neutron fluence with x-ray doses.

By Knowing the neutron fluence and the fluence to dose conversion factor the fast neutron dose was calculated and presented in figure 6 with different photon doses.

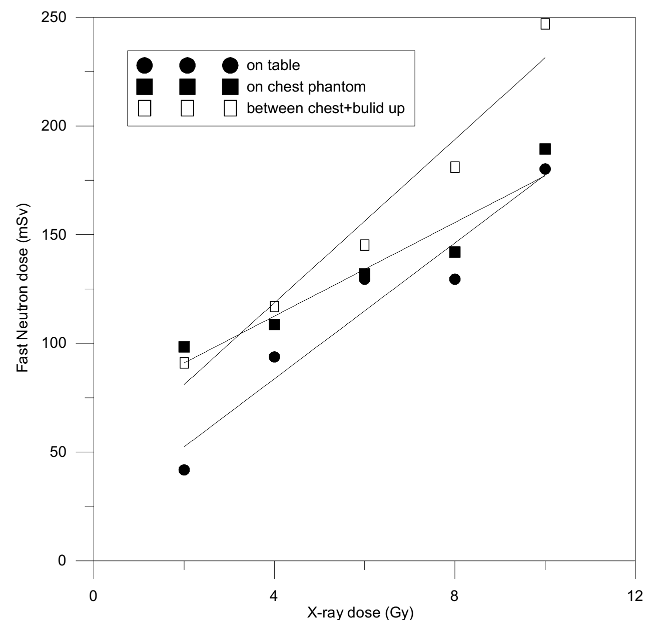

Fig.6: Fast neutron doses with x-ray doses.

4 Conclusions

Wide energy spectra of induced photo-neutrons which are accompanied to high energy photons from medical linear accelerator were measured by NTD. The results showed that the main component of the measured photo-neutron is mainly fast neutrons. Thermal neutron contribution is increased in two cases which are on patient phantom and on addition of build-up Perspex thickness on the phantom. This is due to the thermalization of the fast neutron by the Perspex sheets before reaching the detector. It also refers to the multiple scattering of neutrons between the phantom and the build-up sheets. The total dose measured of fast and thermal neutrons exceeded the maximum permissible dose of public. So, it is recommended to reduce the patient doses of photo-neutrons accompanying the radiotherapy sessions with high energy photons and electrons that considered radio-ecology or radio pollution in environment.

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