Microdosimetric measurements using a research reactor filtered fast neutron irradiation system to biological applications

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Abstract

In this work, microdosimetric measurements were performed using a solid walled Tissue Equivalent Proportional Counter, TEPC, with spherical cavity with an inner diameter of 1.27 cm. The TEPC was filled with pure propane gas, C_3H_8, at 5.6 kPa (42 Torr) pressure, which is equivalent to a 1.3μm diameter, unit density tissue volume. The microdosimetric measurement device was irradiated with fast neutron radiation from Texas A&M University Nuclear Science Center research reactor, in College Station, Texas. The fast neutron beams were measured at three different power values, 0.5, 1.0 and 2.0 kW, for 1hour at both high gain and low gain amplifier settings, totaling two hours for each power. The measurements were made in the heavily filtered fast neutron irradiation system (FNIS), at the Nuclear Science Center, which was designed to obtain a neutron field with low contamination by gamma rays, suitable for cell culture and small animal irradiation experiments. The results show a gamma ray contamination around 5 % of the dose distribution of lineal energy spectra.

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1. Introduction

Gamma radiation is invariably associated with neutrons. Even when neutrons are generated in a nuclear reaction that does not involve prompt photon production, gamma photons are produced as a result of the neutron capture in the environment. Even though the kerma due to photon is smaller than that due to neutron, the count rate due to electrons can be substantial, because for equal kermas the fluence of electrons is up to 100 times larger [1]. Studies with monoenergetic neutrons have been reported in some publications that analyzed how energy is deposited inside of a tissue equivalent proportional counter (TEPC). When neutrons collide with the atoms of the detector wall, charge secondary particles are produced, especially recoil protons. These energy deposition events produce microdosimetric spectra; the frequency distribution of lineal energy and dose distribution of lineal energy. The changes of the neutron lineal energy spectrum with emitted neutron energy and site diameter have been presented in many articles; starting with the first study of Rossi and Rosenzweig [2] and continuing with more recent publications [3-5].

When neutron radiation is contaminated by gamma radiation, the lineal energy spectra show the combination of low and high y events. The combination of neutron radiation and gamma radiation reduces the quality factor relative to a pure neutron field.

In this work we measured the microdosimetric properties of the fast neutron irradiation facility at the Texas A&M University Nuclear Science Center reactor. The microdosimetry spectra were measured at three different powers, levels, 0.5, 1.0, 2.0 kW, inside the heavily filtered fast neutron irradiation system (FNIS) [6]. The FNIS was designed to reduce the gamma ray contamination of the neutron field. The results showed a gamma contamination around 5 % of the neutron absorbed dose inside the irradiation chamber.

2. Materials and Methods

A solid walled Rossi type tissue equivalent proportional counter manufactured by Far West Technology, Inc; Goleta, CA, USA was used for these measurements. The counter is housed in a thin (0.178 mm) aluminum shell which serves as a vacuum tight housing. The active volume of the detector is 1.27 cm in diameter and has a 0.127 cm thick wall of TE plastic. An aluminum stem, 25.4 cm long connects the detector to a connector box which carries the high voltage and signal connectors and a vacuum fitting. Additional equipment included:

- Preamplifier- Camberra – model 2006;
- Spectroscopy amplifier – ORTEC – model 451;
- High voltage supply – ORTEC – model 459;
- Propane gas – C_3H_8;
- Absolute pressure gauge – Wallace & Teimam.

The research reactor of Nuclear Science Center used in this experiment is a TRIGA pool type reactor with a maximum power of 1 MW and has been actively used to isotope production, Instrumental Neutrons Activation Analysis (INAA), and other experimental arrangements such as, delayed neutron counting, neutron radiograph in real time and experiments with beam ports. The shielding capacity is for a reactor operating at 5 MW, which is well above the current 1 MW maximum operating level [7].

The heavily filtered fast neutron irradiation system (FNIS), used in these measurements, provides a cubic cavity with 0.38 m x 0.38 m x 0.49 m inner dimension, suitable for irradiating tissue culture dishes or small animals like rodents. In front of the exposure cave, where the neutron beam enters, lead-bismuth alloy bricks are placed to minimize the gamma radiation, as shown in the fig.1. The system was constructed to reduce photon contamination to 5 % of the neutron absorbed dose.

Fig.1 – Exposure cave showing the lead-bismuth bricks in front where enters the neutrons beams coming from NSC Reactor.

3 – Results and Discussion

The results obtained of the dose distributions of lineal energy using the heavily filtered fast neutron irradiation system is presented on the three spectra of the figure 2. The dose distribution of lineal energy illustrates the dose delivered by the gamma ray and neutron components of the field.

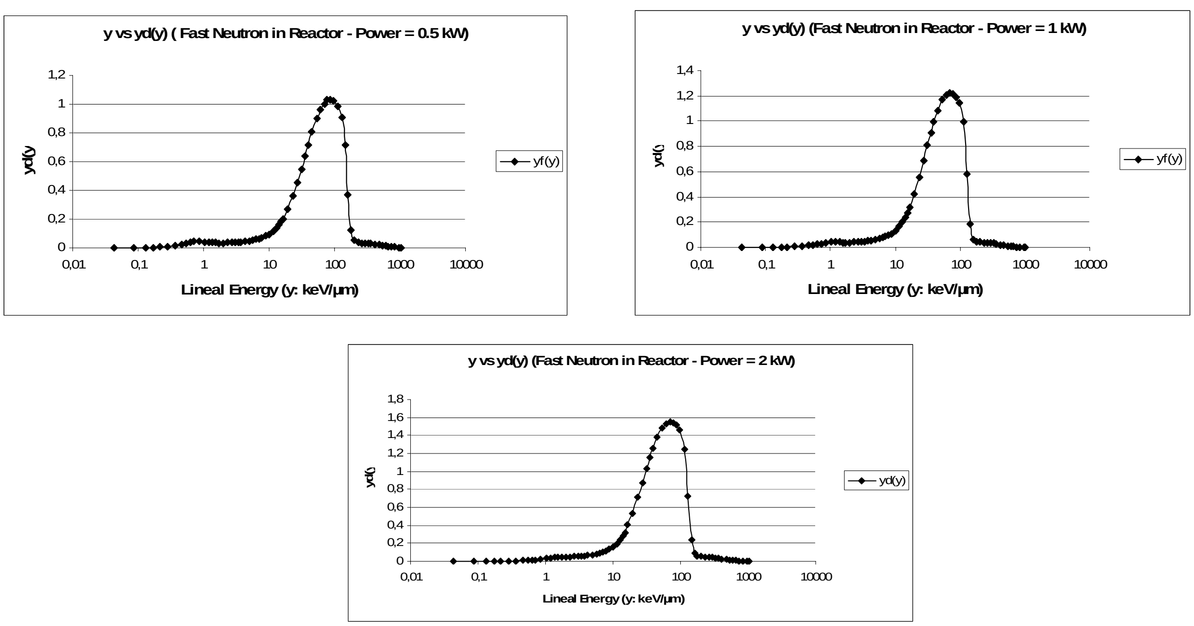

Fig.2 – Dose distributions of lineal energy, log(y) vs yd(y), for fast neutrons, obtained in research reactor. It is showed the spectra for three powers of operation, 0.5, 1.0 and 2.0 kW.

The gamma radiation has a little impact in the dose distribution of lineal energy spectra. The gamma radiation contribution for power of 0.5kW, figure 2, is around 5 %, and in the other two spectra, for 1.0 and 2.0 kW, the contribution of gamma radiation is still smaller, around 3 %. The major contribution for dose distribution is of the recoil proton that is present in this spectrum, from 10.0 keV/µm until the another extremity in 150.0 keV/µm. It is responsible for a contribution in dose distribution that varies from 94 % for reactor power of 0.5 kW until 96 % for reactor power of 2.0 kW.

The results obtained in this work confirm the efficiency of the Filtered Fast Neutron Irradiation System of the Texas A&M University Nuclear Science Center Reactor.

4 – Conclusion

These measurements d(y) inside the heavily filtered fast neutron irradiation system, showed that:

- The heavily filtered fast neutron irradiation system is a powerful tool to gain the neutron radiation spectra without contamination by gamma radiation "in loco", qualifying it to direct biological applications, to study the effects of nearly pure neutron irradiation.
- The maximum gamma radiation contribution to dose distribution of lineal energy, log(y) vs yd(y), is around 5 % but varies with the operation history of the reactor in the hours and days before the measurement.

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