IL9806309

MONTE-CARLO AND DETERMINISTIC ANALYSIS OF MICRODOSIMETRIC PARAMETERS FOR FAST NEUTRONS

[1]A.Taymaz, [2]M. N. Erduran, [3]A. Tutay
[1]Physics Division,Science Faculty, Vezneciler Campus, Istanbul University,
34459 Istanbul - Turkey
[2]Cekmece Nuclear Research Center, Department of Physics, P.K: 1 Hava alani
Istanbul - Turkey
[3]Bareich Schwerionenphysik, Hahn Meitener Institut Berlin, Posfach 39012
D-14091 Berlin - Germany

ABSTRACT. - Ionizing radiations produce biological effects by physical interaction mechanism, i.e., by nuclear and atomic collisions resulting in ionisations and excitations in the irradiated target. Differences in the Radio - Biological Effectiveness (RBE) of the different type of radiation result in a particular type of microdosimetric distribution spectra of the primary radiation products.
Microdosimetric parameters of $\bar{y}_F$, $\bar{y}_D$ and Q are calculated using the Monte-Carlo code in order to characterize these distributions. In addition, ICRP 21 and ICRP 60 data have been used in order to derive the quality factors Q and dose equivalent H for the radiation protection purposes. The discrepancies in microdosimetric parameters may be due to incorrect quality factors for secondary charged particles used in earlier findings and by large statistical errors in many cases.

INTRODUCTION

Microdosimetry originated more than 40 years ago when H.H. Rossi investigated energy deposition in a microscopic tissue material and formulated microdosimetric parameters. Since then microdosimetry has been used in therapy and radio protection. Tissue Equivalent Proportional Counters (TEPC) are constructed as small gas chambers of cylindrical or spherical shape. The target tissue materials are simulated by gas cavities filled with a tissue equivalent mixture of methane and propane base gases at low pressure. The working regime of these counters is already near the operational limit of gaseous detectors. As an alternative to the measurements, a Monte-Carlo modeling of microdosimetric energy deposition distribution has been conducted. These calculations were done for simulation of absorbed dose distribution in microscopic volume of 10 nm to 1000 nm and neutron energies of 1.15 to 20 MeV.
The computer code [1] has included ENDF-VB data file for calculation. It is then possible to calculate energy deposition spectra and quality parameters for any diameter for all the bins extending from 100 keV to 20 MeV.

COMPUTATIONAL MODELING OF PARTICLE TRANSPORT

The absence of an analytical solution for the particle transport for the above target system leads us to choose a Monte-Carlo technique. The Monte-Carlo program simulates the spatial pattern of energy transfer events within the particle track, in a target sizes of nanometric region, where no experimental data exist or insufficient for the event distribution of *f(y)*. The parameters $\bar{y}_F$ and $\bar{y}_D$ are then determined by integrating over calculated or measured *f(y)* and *d(y)* distributions [2].

$$\bar{y}_F = \int_0^\infty y\, f(y)\, dy, \qquad (1)$$

and

$$\bar{y}_D = \int_0^\infty y\, d(y)\, dy \qquad (2)$$

Radiation protection quantities; according to the ICRP 40 [3], the quality factor as a function y;

$$q_n(y) = 5510 \times \left[1 - \exp(1 - (y/141)^2 - (y/171)^3\right] \qquad (3)$$

and the quality factor [4] for neutron energies from 1 to 20 MeV is given by

$$Q = \int_0^\infty d(y, E_n)\, q_n(y)\, dy\,. \qquad (4)$$

The total dose equivalent H is then determined according to

$$H = Q.D \qquad (5)$$

RESULTS AND DISCUSSION

Spectra and dose equivalent distributions are needed not only in therapy planning but also general radiation protection. A knowledge of spectra in the working place is needed so that the appropriate radiation monitoring can be established and that the instrumentations may be properly calibrated. Small variation in microdosimetric spectra may produce significant changes in radiation environment at the working place. The quality and usefulness of a counter is determined by its ability to measure the dose equivalent conversion factor H/Φ and can be used as an indicator of the hardness of a spectrum. The dose distribution of lineal energy is shown in Figure 1. The general features of the distributions, i.e., the observed shifting of the main peak toward the higher values of y indicates decreasing neutron energies. This is agreement with the measured ones [6,7]. Table 1. shows the contribution of different neutron energies to mean values $\bar{y}_F$, $\bar{y}_D$ and quality factors Q calculated using the ICRP 21 and ICRP 60 Q data.

Table 1. Calculated values for $\bar{y}_F$, $\bar{y}_D$ and quality factors Q using ICRP 21 and ICRP 60.

Energy (MeV)	$\bar{y}_F$ KeV/µm	$\bar{y}_D$ KeV/µm	Q 21	Q 60	ΔQ (%)
2.5	31.95	59.40	9.01	12.27	26.6
4.7	21.54	60.49	7.48	9.00	16.8
5.7	18.87	65.13	7.03	8.05	12.7
15.3	11.27	119.63	7.78	7.54	3.2

The mean quality factor $\bar{Q}$ was obtained by integrating the weighted distribution $q_n(y)d(y)$, where $q_n(y)$ approximates the quality factor $Q(L_\infty)$ defined in ICRP21 [4] and ICRP60 [7]. Figure 2. gives the variation of $\bar{y}_F$ and $\bar{y}_D$ with the site sizes for neutron energies 4.7 , 5.7 and 15.1 MeV.

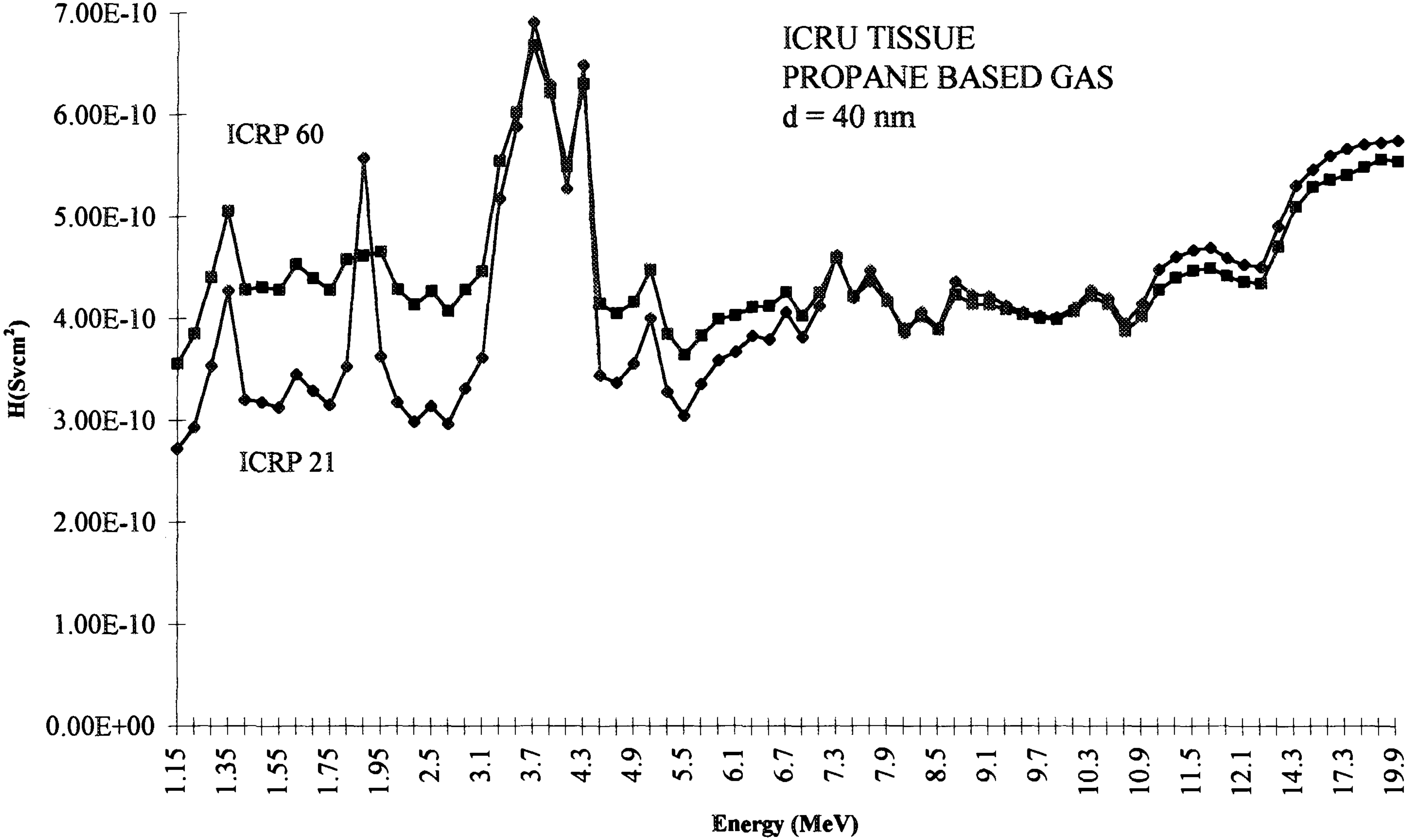

Figure 3. Dose equivalent values plotted against neutron energy using ICRP 21 and ICRP 60 Q data.

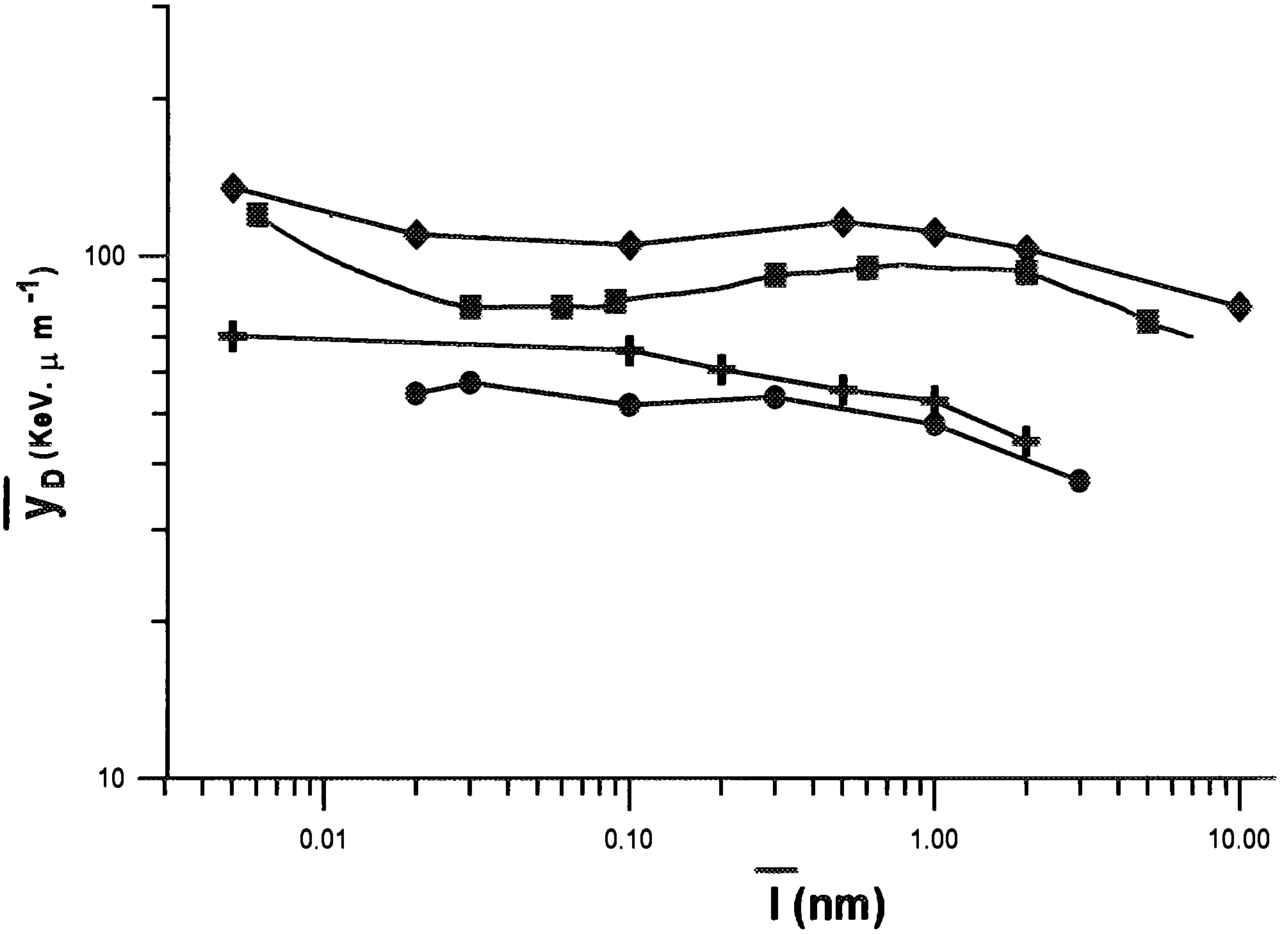

Figure 2. Dependence of the dose mean lineal energy $\overline{y}_D$ on the mean chord length $\overline{l}$ for 15.1 MeV(◆), Ref. (8) 15 MeV (■), 5.7 MeV (✚) and 4.7 MeV (●) neutrons.

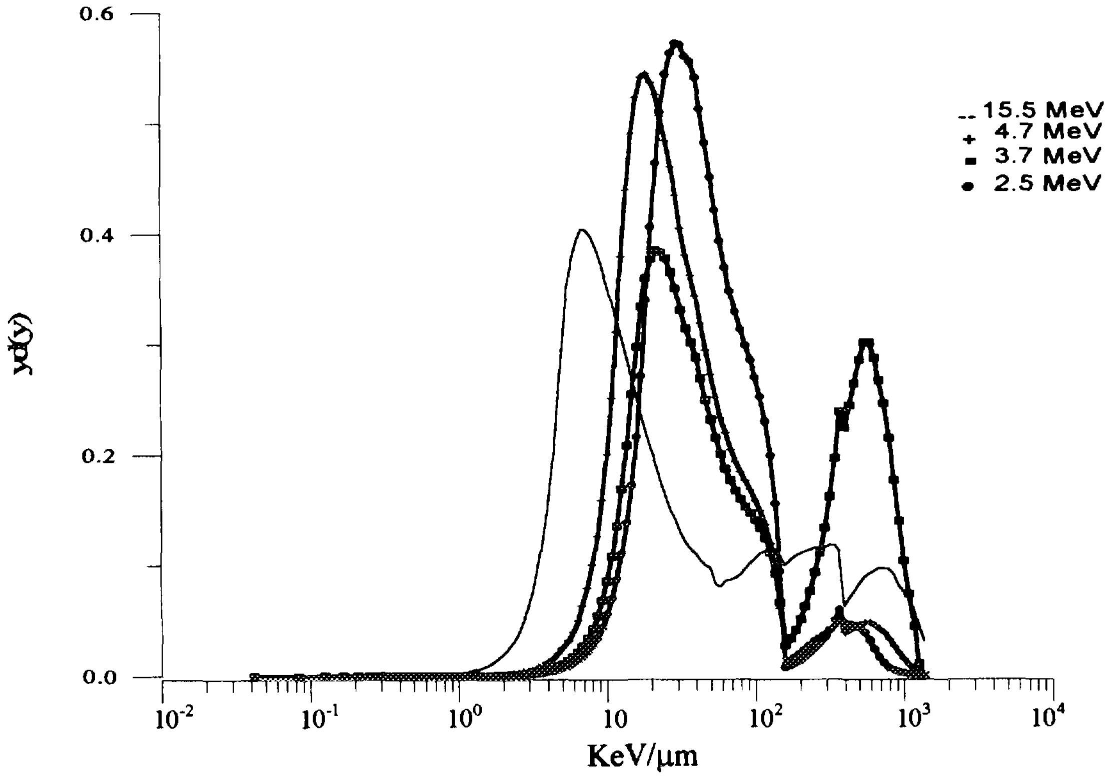

Figure 1. Microdosimetric dose distributions in 1000 nm site size for 2.5, 3.7, 4.7 and 15.5 MeV neutron energies.

Our results for 15.1 MeV neutrons and 10 nm site size are 111.3 KeV.µm^{-1} for $\overline{y}_D$ and 11.4 KeV. µm^{-1} for $\overline{y}_F$ respectively. Reported $\overline{y}_D$ value, for the 15.1 MeV neutron energy and 10 nm site size is 12.5% smaller than our result. For other neutron energies, our results differ from the reported $\overline{y}_D$ from 0.2. to 10.2 %.

Figure 3. shows the influence of the ICRP 21 and ICRP 60 Q data on the dose equivalent H for the given site sizes and the neutron energies. Differences in the H values come from recommended (4,7) Q values. There are also due to incorrect quality factors for secondary charged particles used in earlier findings. In our findings, these differences between dose equivalents for the new and old Q relationships vary between 2 - 30 % in many cases.

REFERENCES

[1] R.S. Caswell, J.J. Coyne and B.L. Siebert, C and O For Fast Neutrons in Materials Composed of H, C and O. PP1 132-1141 Radiation Protection, EUR 8395 Belgium 1983.,

[2] H.H. Rossi, Microdosimetric Energy Distribution in irradiated Matter Radiat. Ed. Vol. 1, Ed. by Attix, F.H and Roesch, Academic Press, N.Y., p 49 - 92, 1968

[3] ICRU Microdosimetry Report 40, The quality factor in Radiation Protection, Bethasda, MD, USA 1986.

[4] ICRP Data for Radiation Protection Against Ionizing Radiation from External Sources, Publication 21, Oxford Pergamon Press 1973.

[5} E.Anachova, A.M. Kellerer and H.H. Ross, Neutron Energy Deposition Spectra at Simulated Diameters down to 50 nm., Rad. Prot. Dosimetry, Vol. 70, 207-219 (1997).

[6] L. Lingborg, S. Marino, P. Kliauga and H. H Rossi, Microdosimetric Measurements and the Variance- Covariance Method, Radiat. Environ. Biophys, 28(4), 251-263 (1989)

[7] ICRP International Commission on Radiological Protection Publication 60, Oxford Pergamon Press 1991.

(8) Lindborg, L. ,Marino.S., S. Kliauga, P. and Rossi, H.H
Microdosimetric Measurements and the variance - covariance method. Radiat. Environ. Biophys. 28 (4), 251-263 (1989).