LET DISTRIBUTION OF ABSORBED DOSE IN A MIXED RADIATION FIELD AROUND AN ELECTRON LINEAR ACCELERATOR

Keiji ODA, Hiroshi KOYAMA, Takayoshi YAMAMOTO and Masaharu KAWANISHI

The Institute of Scientific and Industrial Research, Osaka University Mihogaoka, Ibaraki, Osaka 567

1. Introduction

Ionizing radiations around high-energy particle accelerators, in general, form a mixed field consisting mainly of X-rays and neutrons. It is one of purposes in dosimetry of such a field to evaluate the dose equivalent (DE). It is desirable for DE evaluation to measure energy spectra of respective radiations, but in practice a separate measurement in a mixed field is very difficult. In addition, all the spectrometers, which is based on a time-consuming was that a radiation pulse is accumulated in a PHA one by one, can never be used in a high-fluence-rate field as well as a single-burst one. Thus, we proposed a method with an abreast-type ionization chamber in the previous paper.[1] According to the method, the total absorbed dose due to all radiations can be accurately determined if the collected charge would be corrected by the collection efficiency, and the average quality factor (QF) can be estimated from the average recombination coefficient which is regarded as a parameter of the ratio of a mixture of X-rays and neutrons.

In this report, the applicability of the proposed method is confirmed by comparing with other ones in a reference field generated by an electron linear accelerator. A spherical tissue-equivalent (TE) proportional counter is used for evaluating an LET distribution of the absorbed dose. The DE, in this case, can be obtained by integrating the product of the absorbed dose and QF as a function of LET.

2. Measurement of LET Distribution of Absorbed Dose

A method for evaluating LET distribution of absorbed dose in tissue has been already proposed and established by Rossi [2,3] According to the procedure, experiments were carried out with a TE proportional counter. A mixed radiation field was generated by an electron linear accelerator installed at ISIR, Osaka University, of which output current was adjusted as low as possible in order for duplicate radiation pulses not to enter into the counter. An example of the experimental results is shown in Fig. 1, where the LET on the abscissa has beforehand been calibrated by a reference source. In a mixed field consisting of X-rays and neutrons, ionization takes place by secondary electrons and recoil protons. Their LET's distribute widely from about 0.1 to 91 keV/μm. Aspecial instrument such as a log-amplifier must be required when one measures directly their LET's in wide range with a PHA. Furthermore, it is very difficult to eliminate electronic noises from signals due to electrons, because the heights of both pulses are often comparable with each other.

Thus, we tried using the counter in combination with an ionization chamber to evaluate DE in the mixed field. The DE, H, is expressed as follows:

$$H = \int_0^\infty QF(L)\,D(L)\,dL = \int_0^{3.5} D(L)\,dL + \int_{3.5}^\infty QF(L)\,D(L)\,dL$$

$$= D_t + \int_{3.5}^\infty [\,QF(L) - 1\,]\,D(L)\,dL \ ,$$

where $D(L)$ is the absorbed dose per unit LET, which is evaluated for LET higher than 3.5 keV/μm with the TE proportional counter, and D_t is the total absorbed dose, which is measured with an ionization chamber. The DE then can be evaluated even though one does not know the LET distribution for LET lower than 3.5 keV/μm.

3. Discussions

From a target bombarded by high-energy electrons, most of bremsstrahlung X-rays are emitted forward and photo-neutrons nearly isotropically. The total absorbed dose varies with the beam current, the pulse duration, the distance from the target, etc. At a constant beam energy, however, the average QF ($\overline{QF} = H/D_t$) becomes a function of only the angle with respect to the incident electron beam. The average QF becomes large with increasing the angle because of different emission characteristics between X-rays and neutrons.

The angular dependence of the average QF was measured in such a way as mentioned above, and the results are shown in Fig. 2 by dots. The symbol □ represents the results obtained by the proposed method with an abreast-type ionization chamber previously reported. In addition, the results obtained by the separate measurement of both X-ray and neutron doses with two ionization chambers with different sensitivities to neutrons are shown by the symbol ■. The average QF in this method is obtained by substituting the evaluated separate doses, D_x and D_n, into the following equation:

$$\overline{QF} = (D_x + \overline{QF}_n D_n)/(D_x + D_n) ,$$

where $\overline{QF}_n$ is the neutron quality factor, which was determined to be 10.2 by averaging QF weightened by the particle fluence as a function of neutron energy measured by the activation method and TOF one.[4] A good agreement is found among the results by three methods. It is confirmed that the angular distribution of the average QF could be accurately obtained by the proposed method in the mixed radiation field around the linear accelerator.

References

[1] K.Oda, T.Yamamoto and M.Kawanishi: Nucl. Instr. Meth. (1982), in press.
[2] H.H.Rossi: Rad. Res. 10 (1959) 522.
[3] H.H.Rossi: *Radiation Dosimetry, vol. I*, eds. F.H.Attix and W.C.Roesch (Academic, New York, 1968) Chap. 2.
[4] J.Ohkuma: private communication.

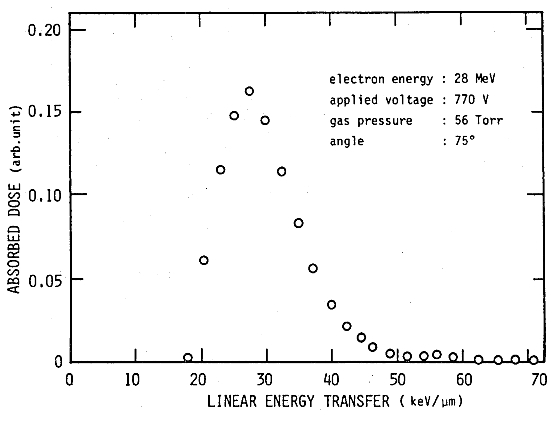

Fig. 1. LET distributibution of absorbed dose evaluated with a TE proportional counter. Electron energy: 28 MeV, angle: 75°.

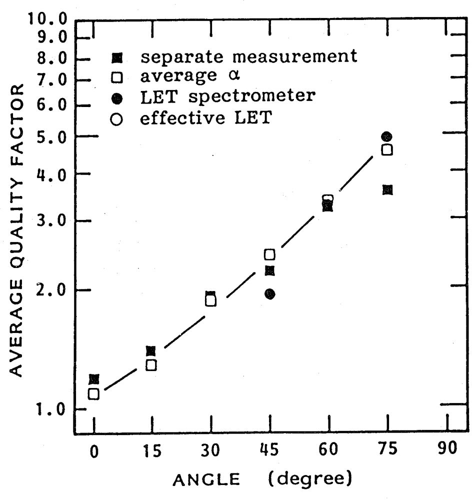

Fig. 2. Angular dependence of average QF obtained by three methods. Electron energy: 28 MeV.