Sci. J. Fac. Sci. Menoufia Univ. Vol. IX (1995). 299 - 310

INVESTIGATION OF NEUTRON DOSES IN WATER

Mohamed Bassiouny
Basic and Applied Science Department,
College of Engineering and Technology,
Arab Academy for Science and Technology
Alexandria, EGYPT.

ABSTRACT

Thermal, intermediate and fast neutron fluxes from compact D-T neutron generator have been measured inside a tissue equivalent medium(water). The method is based on the measuring of induced activities produced by the activation foil technique. The fluence dose conversion factors as well as related quality factors were used to determine the dose equivalent. The contribution of thermal and intermediate neutron doses is less than 1% of the total dose.

INTRODUCTION

The use of neutrons in therapy requires accurate physical dosimetry. It is very important to specify in details the spatial distribution of absorbed dose rate in a tissue equivalent medium [1-3]. D-T neutron distributions were determined inside the media by using the activation foil technique [4-5]. If one has a measure of neutron flux then the dose rates could be calculated using the ICRP data [6].

The question of neutron spectrum dependence must be raised for calculated as well as measured data. Size of detector has a great importance as each measure of the dose at a point involves integration of energy deposition over the region of the detector [7]. The use of activation foils as a neutron detectors [8] shows by their small thickness good properties close to the neutron source.

The aim of this work is to investigate the flux and dose distribution for D-T neutrons inside a water phantom with dimensions (30x30x20) cm^3.

EXPERIMENTAL

The ~~measurements were carried out with D-T compact neutron~~ source of Phillips type PW5310, yield 1.1×10^8 $n.s^{-1}$ and 14.5 MeV neutron energy. The spectrum of generator was examined by activation foil technique [5]. Tab. 1 gives the characteristics of the used foils and the considered reactions which used to determine either fast or thermal neutron fluxes as well as the convenient times of irradiations.

In addition cadmium foils were used to cut off thermal neutrons from diffused spectrum. Foils were supplied by BDH England and Reactor Experiments Inc. San Carlos, California, U S A.

Table 1: The characteristics of the used foils.

Foil	Radius (cm)	Thickness (mm)	Reaction of interest	Threshold energy	$T_{1/2}$	T_i
Zn	1.30	1.83	$^{64}\mathrm{Zn}(n,2n)^{63}\mathrm{Zn}$	12.10	38.0m	40.0m
Cu	1.40	0.10	$^{63}\mathrm{Cu}(n,2n)^{62}\mathrm{Cu}$	11.00	9.8m	10.0m
Al	1.84	1.00	$^{27}\mathrm{Al}(n,\alpha)^{24}\mathrm{Na}$ $^{27}\mathrm{Al}(n,p)^{27}\mathrm{Mg}$	3.25 1.90	15.0h 9.4m	6h 10m
In	1.37	1.00	$^{115}\mathrm{In}(n,n')^{115m}\mathrm{In}$ $^{115}\mathrm{In}(n,\gamma)^{116m}\mathrm{In}$	0.34 -----	4.5h 54.2m	2h 2h

$$A = C\int_{E_t}^{E_m} \sigma(E)\,\phi(E)\,dE....... \qquad (1)$$

The produced apparent activities of the radioproducts (table 1) were measured by NaI(Tl) scintillation crystal 3" x3" connected to a multichannel analyzer Canberra series 40. Fig. 1 gives the efficiency of the used spectrometer. Proper corrections were applied to the apparent activity in order to get the actual activity A. The differential flux in each energy region was determined by applying the successive stepwise approximation method [5], where A is related to the differential flux ϕ (E) by the relation:

The elemental mass of the detector, the relative abundance, the atomic weight, Avogadro's number and corrections for activation and decay time are coupled together as constant C. σ (E) is the energy integral of the activation cross section between E_t and E_m where E_t is the threshold activation energy of the detector and E_m is the cut-off neutron energy. σ (E) could be determined from the available literatures [9]. Normalization corrections had to be applied to all activations using a neutron monitor [5].

After deduction of the fast neutron flux for each energy region from 14.5 MeV to 0.34 MeV, the absorbed dose D(E) is determined by using ICRP conversion factors and calculated by using the equation(1).

$$\mathbf{D(E) = \phi(E)\,\bar{E}(\bar{\sigma}_{ai}\,n_i + F_i\,\bar{\sigma}_{si}\,n_i)} \qquad \mathbf{(2)}$$

where:

ϕ (E) is the distribution of the neutron flux with respect to energy,

$\bar{\mathbf{E}}$ is the average neutron energy in each region,

$\bar{\sigma}_{ai}$, $\bar{\sigma}_{si}$ are the average absorption and scattering cross sections of the ith element in each energy region,

n_i is the number of atoms for unit mass of ith element,

F_i is the average fractional energy transfer to the scattered atom.

As one has calculated the absorbed doses then it is easy to find the equivalent dose rates according to the following equation [1]:

$$\mathbf{DE = D\ (E)\ x\ \overline{QF}} \qquad \mathbf{(3)}$$

where **DE** is the equivalent dose rate and $\overline{\mathbf{QF}}$ is the average quality factor in each energy region.

The accumulation of the scattered neutrons at deep depths within the phantom is yielding the build-up factor $B_D(E,r)$ which is defined as:

$$\mathbf{B_D(E,r) = (\frac{D(E,r)}{D(E,o)})\, e^{-\Sigma_t r}} \qquad (4)$$

RESULTS AND DISCUSSION

Figure(2) represents the integrated fast neutron flux overall different energy groups, while figure(3) represents the variation of intermediate and thermal neutron fluxes with the distance inside the phantom. It is clear that the integrated fast neutron flux (14.5-0.34 MeV) decreases gradually with distance which is in a good agreement with both the theoretical and experimental published data [3,10]. On the otherhand, the intermediate and thermal neutron fluxes show a maximum at around 2.5 cm inside the phantom. These maxima are attributed to the scattering processes occur inside the phantom between the diffused neutrons and hydrogen nuclei.

Making use of equation(2) and ICRP data [6], the absorbed doses and dose equivalent rates were determined and calculated for the different energy regions. These results are reproduced in figures (4,5). A good agreement was found between the determined and calculated doses. Also the variation of the dose build-up for integrated fast neutron with depth in the considered medium is represented in figure(6). It is clear that the dose build-up is dependent on the average scattering and the total macroscopic cross-sections. The data presented in this work isof great help in the field of neutron therapy.

ACKNOWLEDGEMENT

The author would like to express his deepest gratitude to Prof. A. El-Khatib and Prof. M. A. Fawzy ; Faculty of Science , Alexandria University ,for their continuous guidance and fruitful discussions.

REFERENCES

1- H. Cember:Introduction to Health Physics. Pergamon press Ltd. Oxford,U.K.(1985).

2- H. E. Jones and J. R. Cunningham: The Physics of Radiology, Thamas Chales Publisher, Spring Field, Illinois, USA (1983).

3- A. M. Sayed, N. A. Alliabi, Spectral Distribution of Neutron Dose in Phantom, Isotopen -praxis 20, 416 (1984).

4- A. M. El-Khatib, W. M. Abou-Taleb, M. A. Fawzy, K. E. Gado: Neutron Dosimetry in Polyvinyl Chloride by Activation Foil Technique. J. Radiation Effects and Defects in Solids, 132, 63 , (1994).

5- Y. S. Selim, A. M. El-Khatib, W. M. Abou-Talib, M. A. Fawzy: Determination of Average Differential Neutron Flux in Matter by Threshold Detectors. Arabian J. Sci. Eng. 8, 4 (1983).

6- ICRP: "Data for Protection Against Ionizing Radiation from External Sources; Supplement to ICRP Publications", Adopted by the Commission in April 1971. ICRP Publication 21, Pergamon Press, Oxford (1973).

7- K. H. Beckurtz and K. Writz: Neutron Physics. New York; Spring-Verlag (1964).

8- A. M. El-Khatib: "Energy and Radial Distribution of Fast Neutrons", Ph. D. Thesis, Physics Dept., Alexandria University (1981).

9- D. I. Garber and R. R. Kinsey: "Neutron Cross Sections BNL-325", Brookhaven National Lab. Upton, N. Y.,USA (1978).

10- National Council on Radiation Protection and Measurements Proceeding of the Twentieth annual Meeting, 4-5 April, (1984).

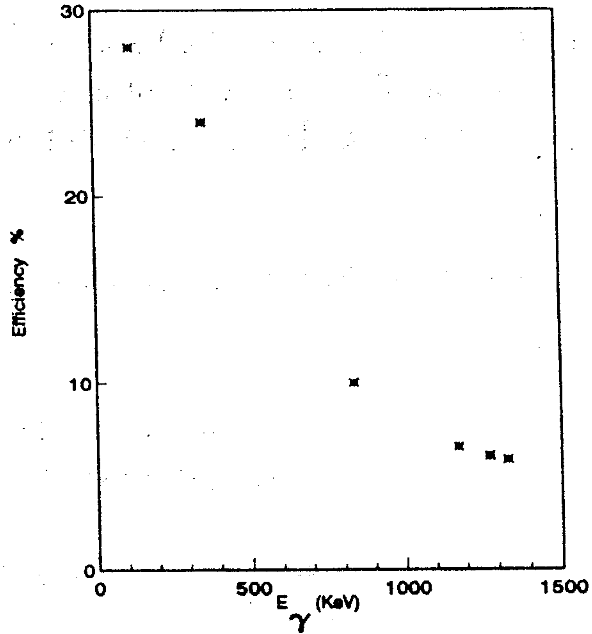

Fig. 1: Efficiency of the used spectrometer

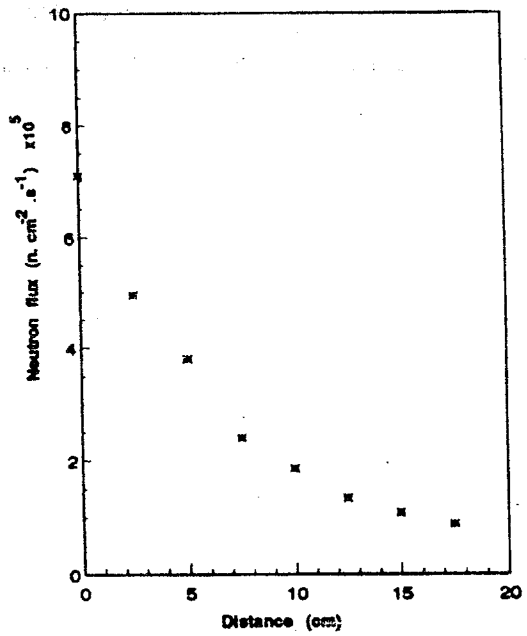

Fig. 2: The integrated fast neutron flux overall energy groups.

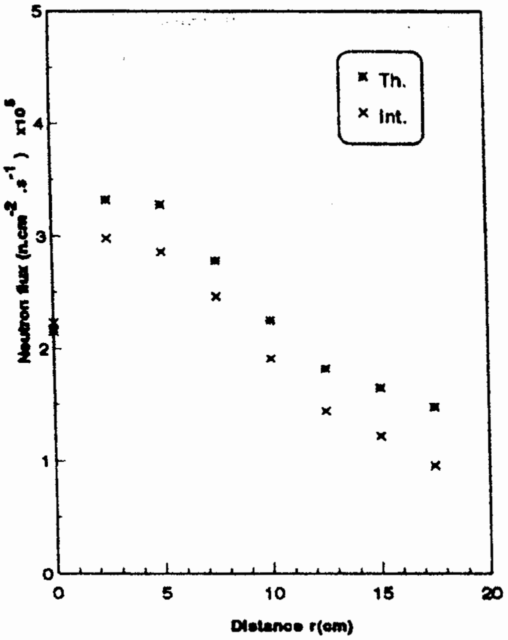

Fig. 3:Variation of intermediate and thermal neutron fluxes.

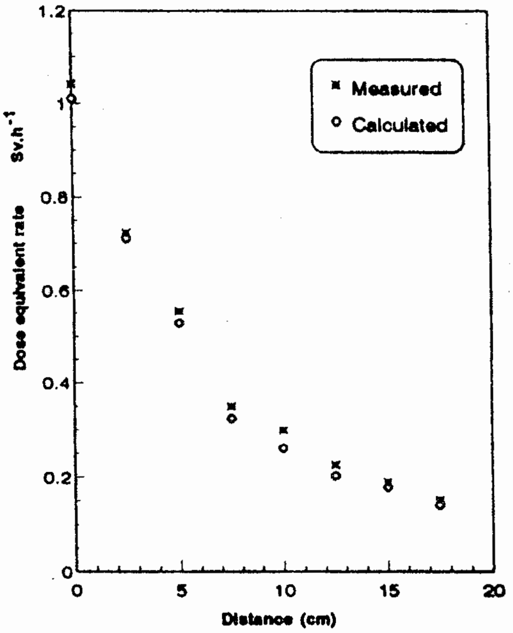

Fig. 4:Equivalent dose rate of fast neutrons.

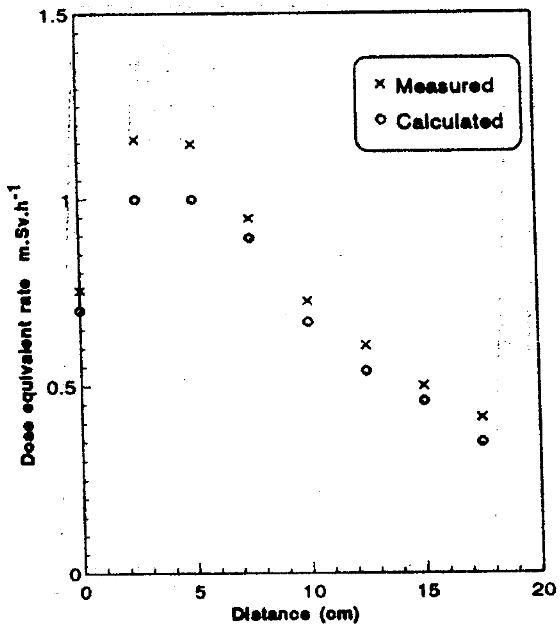

Fig. 5-a:Equivalent dose rate of thermal neutrons

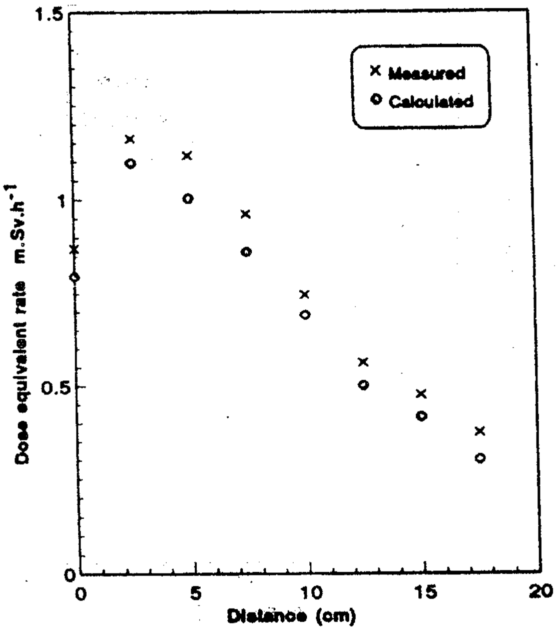

Fig. 5-b:Equivalent dose rate of Intermediate neutrons.

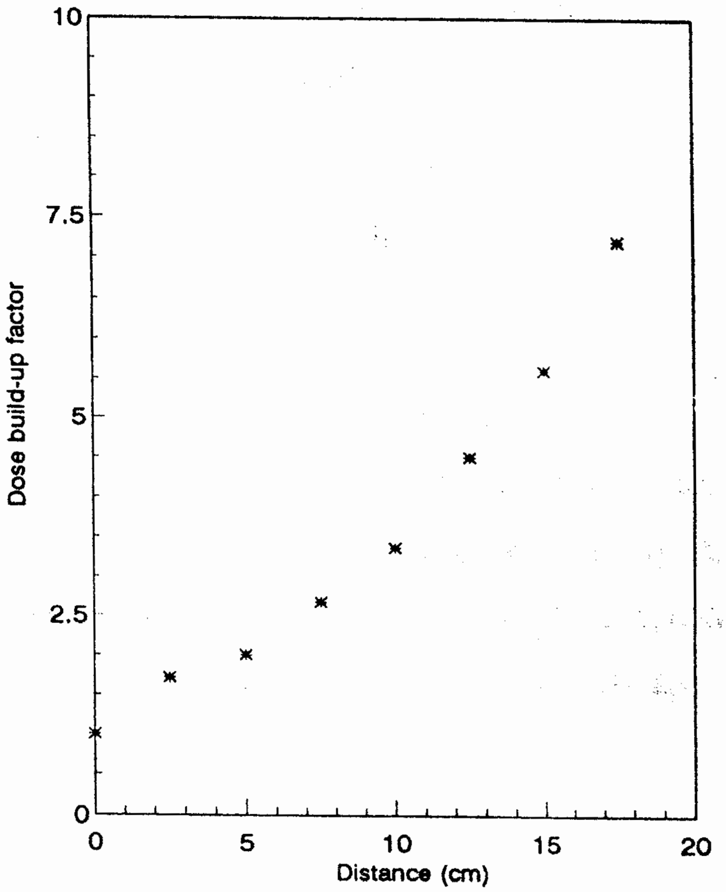

Fig. 6: Dose build-up for fast neutrons

تحديد الجرعات النيوترونية داخل الماء

محمد بسيوني

قسم العلوم الأساسية – التطبيقية

كلية الهندسة والتكنولوجيا – الأكاديمية العربية للعلوم والتكنولوجيا

ملخص البحث

تم فى هذا البحث تعيين التوزيع الطاقى والمكانى للسيل النيترونى المتولد من أنبوبة نيوترونية د + ت. وذلك عند انتشارها داخل جسم مكافىء للإنسان (الماء) . وقد تمت القياسات بإستخدام طريقة التنشيط الأشعاعى للكواشف العتبية. حيث تم أستنتاج السيل النيوترونى المنتشر فى داخل الجسم ومن ثم حسبت الجرعة الأشعاعية الكلية .