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DETERMINATION OF ABSORBED DOSE TO THE LENS OF EYE FROM EXTERNAL SOURCES

Chen Lishu
China Institute of Atomic Energy, Beijing P.R.China

ABSTRACTS

The methods of determining absorbed dose distributions in human eyeball by means of the experiments and available theories have been reported. A water phantom was built up. The distributions of beta dose were measured by an extrapolation ionization chamber at some depthes corresponding to components of human eyeball such as comea, sclera,anterior chamber and the lens of eye. The ratios among superficial absorbed dose (at 0.07 mm) and average absorbed doses at the depthes 1,2,3 mm are obtained. They can be used for confining the deterministic effects of superficial tissues and organs such as the lens of eye for weakly penetrating radiations.

1. INTRODUCTIONS

Different tissues or organs vary in their response to ionizing radiations. Among the rest the most radiosensitive tissues and organs are ovary, teste, bone marrow and the lens of eye. Threshold doses for some deterministic effects resulting changes in function in these tissues and organs are shown in Table 1. The recommendated limits of effective dose and equivalent dose to the lens of eye for workers and the members of Public have been decreased in 1990 Recommendation of the International Commission on Radiological Protection (ICRP Publication 60) [1] as compared with the ICRP Publication 26 (1977) [2]. For wokers the annual limit is 150 mSv. For individual members of the public the annual limit of 15 mSv has been adopted.

Table 1. Estimations of the threshold for deterministic effects in the adult human testes, ovanies, lens of eye and bone marrow (From ICRP 41)[3]

Tissue and effect	Total dose equivalent received in a single brief exposure, Sv	Total dose equivalent* Sv	annual dose rate** Sv/a
Testes			
Temporay sterility	0.15	No application	0.4
permanent sterility	3.5-6.0	No application	2.0
Ovaries			
sterility	2.5-6.0	6.0	>0.2
Lens			
detectable opacities	0.5-2.0	5	>0.1
visinal impairment (cataracit)	5.0	>8	>0.15
Bone marrow			
depression of hematopoieists	0.5	No application	>0.4

** Received in highly fractionated or protracted exposure*

***Received yearly in highly fractionated or protracted exposure for many years.*

The quantity of interest in radiation protection is equivalent dose, H_T, in each tissue or organ (T). This is the quantity to which the Commission's annual dose limits for deterministic effects basically apply. The restrictions on effective dose are sufficient to ensure the avoidance of deter- ministic effects in all body tissues and organs except the lens of the eye and skin. Thus they will not necessarily be protected against deterministic effects. Therefore the equivalent dose limits to the lens of the eye and skin are excluded from compution of effective dose and are provided separately when considering the protection for individuals against ionizing radiations.

The superficial individual absorbed dose $D_p(0.07)$ and directional absorbed dose $D'(0.07)$ for weakly penetrating radiations are usually measured in radiation protection practices[4][5] The objective of the paper is to establish the relationships between the average absorbed dose to the lens of eye and the two quantities by two means for external exposure.

2. DETERMINATION OF THE ABSORBED DOSE DISTRIBUTIONS IN A WATER PHANTOM

A. considerations in theory

The quantities of interest in radiation protection are the equivalent doses in each tissue or organ (H_T). In the circumstance of external exposure from weakly penetration radiations the radiation weighting factors are taken to be unity. Therefore the equivalent dose equals to the average absorbed dose over tissue or organ of interest in numerical value.

For protection of the lens of eye the measurement or estimation of average absorbed dose are basic link in practices. However,it is immeasurable directly. Its values are only obtained by extrapolating the dosimetric quantities with some models.

In general, there are two approaches to beta dosimetric problem for external exposure,e.g. computation and experiment.

Some theoretical calculations are based on following ways:

a. Absorbed dose distributions around a point isotropic source in an infinite homogeneous medium provide a basis for calculation of beta doses from any spatially distributed source in the medium [6].

b. Point source functions for monoenergetic electrons in several media have been tabulated by Spencer [7] and Berger [8].

c. General solutions of Age-diffusion theory and transport theory for beta ray dosimetry are capable of tackling the problem [9] [10].

These treatments are confined to an assumption of electrons slowing down continuously. They exclude the contributions from gamma-, x-rays or bremsstrahlung and Auger electrons, and apply only to infinite homogeneous media. They are also inapplicable for absorbed doses at an interface. From Loevinger's semiempirical relationships [6] it is obvious that absorbed dose of a point source at an interface (r=0) will necessarily be divergent. Besides, theoretical models hardly ever take into account many anatomical and physical factors in practices.

As an example of calculation the percentage doses contributed from individual strontium and yttrium spectrum unfiltered to their total absorbed dose at different depthes were obtained using the solutions of Age diffusion theory. It is proved that the absorbed doses delivered by ^{90}Sr and ^{90}Y respectively are inequable each other anywhere except at about 65 mg/cm^2 (see Table 2 and Figure 1).

Table 2. Percentage doses contributed from ^{90}Sr and ^{90}Y espectively to total dose.

Depth, mg/cm^2	^{90}Sr	^{90}Y	Depth, mg/cm^2	^{90}Sr	^{90}Y
0	0.95	0.05	40	0.75	0.25
3	0.94	0.06	60	0.55	0.45
7	0.93	0.07	70	0.43	0.57
10	0.92	0.08	80	0.32	0.68
20	0.88	0.12	100	0.16	0.84

B. Considerations in experiment

Penetration of electrons in a medium is completely determined by two reasonally well-known quantities, the stopping power (dE/dX) and mass attenuation coefficient μ_{en}. So the interactions of beta radiations with components of a eyeball are more similer to water than other materials. In order to imitate these tissues of interest a physiologic saline (0.9 %)

phantom contained in a topless and bottomless cylinder made of polystyrene was adopted except in so far as a piece of thin film acted as the bottom. A correction has been applied to accout of its attenuation.

A uniform radiation field of broad beams was realised by a strontium + yttrium plane source filtered by 100 mg/cm^2. In this instance, the absorbed doses come from Yttrium mainly.

The average absorbed dose at various depthes up to 6 mm were measured by means of an extrapolation ionization chamber made of tissue equivalent material[11]. The lens of eye and skin lie in respectly the depthes 3 and 0.07 mm recommended by ICRP.

Besides, the cornea, sclera and lens were separated anatomicically from a fresh eyeball. Then their attenuations for ^{90}Sr + ^{90}Y radiations have been determined.

3. MEASUREMENT RESULTS

A. Absorptions and equivalent thicknesses of eyeball components for ^{90}Sr + ^{90}Y radiations are shown in Table 3.

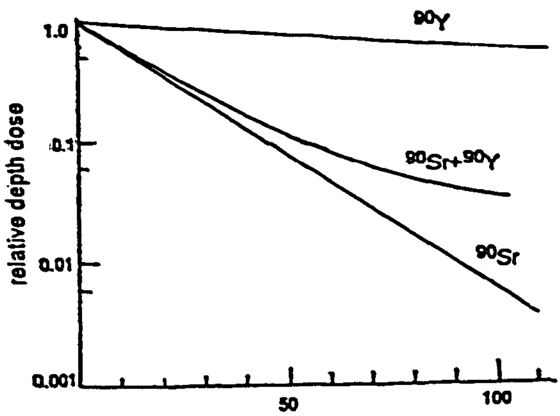

Figure 1. Dose contributions from respective ^{90}Sr, ^{90}Y and ^{90}Sr + ^{90}Y

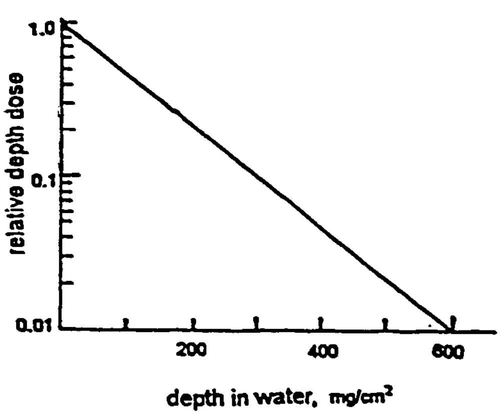

Figure 2. Relative depth dose distributions of a ^{90}Sr + ^{90}Y filtered by 100 mg/cm^2

Table 3. Percentage attenuations and corresponding thicknesses of eyeball components for ^{90}Sr + ^{90}Y radiations

Component name	Absorption %	Equi. thickness mm, water
Cornea	0.42	0.72
Sclera	0.31	0.49
lens	0.78	2.5
anterior Chamber	0.90	3.0
	0.95	4.0

B. Average absorbed doses to water phantom at defined depthes of interest where the tissue and organ lie in were measured. The relative depth doses are shown in Figure 2. The ratios of average absorbed doses at some depthes relative to surperficial dose at 0.07 mm are obtained and listed in Table 4 along with the results obtained by other authores. Items 1-5 are computational values utilizing Cross' Tables [14]. Item 6 is the experimental values, and 7 and 8 come from Friedell [10] and Snaroff [13].

Table 4. Ratios of absorbed doses at various depthes related to superficial dose for some radionuclides.

radionuclides	half-life	Emax. MeV	E meV	D(0.07)	D(1)	D(2)	D(3)	D(4)	D(5)	D(6)
1. ^{204}Tl	3.78y	0.776	0.243	1.00	0.047					
2. ^{32}P	14.3d	1.718	0.695	1.00	0.273	0.103	0.037	0.0092		
3. ^{24}Na	15h	1.39	0.54	1.00	0.215	0.059	0.012	0.0013		
4. ^{106}Ru	1.01y	3.54		1.00	0.42	0.26	0.188	0.141	0.094	0.061
5. ^{90}Sr+^{90}Y	26.5y	2.274		1.00	0.193	0.10	0.053	0.027	0.007	0.042
6. present experiment				1.00	0.46	0.24	0.10	0.048	0.022	0.011
7. ref.12				1.00	0.41	0.19	0.09	0.04	0.01	
8. ref.13				1.00	0.50	0.25	0.15	0.06	0.028	

C. Radiation effects depend on the depth which the lens of eye lie in. Considering that several components exist in front of lens and eyeball can be stretched out and drawn back as well as individual discrepancy, the dose at the front surface of the lens is about 3%-7% of surperficial dose,and 0.6%-1.5% at behind the lens.

4. CONCLUSIONS

It is shown that the results of present work has a satisfactory agreement with experiments of other authores[12, 13]. The discrepancy between theoretical calculation and experiment is due to the fact that a practical filtered spectrum was used in the experiment. The restriction on facial skin dose is sufficient to ensure the avoidance of deterministic effects in the lens of eye for some weakly penetrating radiations. In radiotherapeutic exposure, the absorbed dose to tissues are in general very much higher and both the dangers of the exposure and the benefits of the treatment can be assessed more quantitatively. But sometimes, for example, the therapeutic dose of vernal catarrh is about 18-169 Gy, the radiations play no useful part for the lens of eye and are merely adventitious. At the time, the absorbed dose constraints must be applied for controlling exposures. Thus the lens of eye should necessarily be protected against deterministic effects.

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