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ABSTRACT

The International Commission on Radiological Units and Measurements (ICRU) has defined several new operational quantities for radiation protection purposes. The quantities to be used for personal monitoring are defined at depths in the human body. Because these quantities are impossible to measure directly, the ICRU has recommended that personal dosemeters should be calibrated under simplified conditions on an appropriate phantom, such as the ICRU sphere. The U.S. personal dosimetry accreditation programs make use of a 30 x 30 x 15 cm polymethylmethacrylate (PMMA) phantom, therefore it is necessary to relate the response of dosemeters calibrated on this phantom to the ICRU operational quantities. Calculations of the conversion factors to compute dosemeter response in terms of the operational quantities have been performed using the code MCNP. These calculations have also been compared to experimental measurements using thermoluminescent (TLD) detectors.

INTRODUCTION

The ICRU has defined four operational quantities that are recommended for radiation protection (ICRU, 1985). The ambient and directional dose equivalents are to be used for the environmental, or area, monitoring of strongly and weakly penetrating radiations, respectively. These quantities are specified at depths in the ICRU sphere (ICRU, 1980). The quantities for personal monitoring are the individual dose equivalents, penetrating and superficial. These quantities are also defined for strongly and weakly penetrating radiation, respectively. The individual dose equivalent quantities are specified at depths in the human body, so it is impossible to measure them directly. In practice, a personal dosemeter is constructed so that the detecting element is covered by an appropriate amount of tissue-equivalent material, and this dosemeter is then calibrated on a simplified tissue-equivalent phantom. However, most dosemeters in use in the U.S. are sensitive to backscattered radiation from the body and from calibration phantoms. When calibrations are performed with dosemeters mounted on a PMMA slab phantom, corrections must be applied to account for differences in backscatter between the PMMA phantom and the ICRU sphere.

In the U.S., there are two programs for the accreditation of personal dosemeters. They are the Department of Energy Laboratory Accreditation Program (DOELAP) and the National Voluntary

Laboratory Accreditation Program (NVLAP). These programs require the use of a rectangular PMMA phantom (DOE,1986, ANSI,1983). Therefore, conversion factors are needed to relate the response of dosemeters irradiated on a PMMA phantom to the operational quantities. Calculations of this type have been performed for photon and neutron irradiations (Hertel and McDonald, 1990, 1991).

CALCULATIONS AND MEASUREMENTS

The determination of values for conversion factors can be accomplished either by calculation or measurement, or both. The most desirable situation is to use both methods and compare the two. It has been the approach at the Pacific Northwest Laboratory to use the Monte Carlo computer code MCNP (ORNL, 1983) and to perform confirmatory measurements in a geometry that closely approximates the conditions used in the irradiations for the accreditation programs.

The first case considered in the calculations was for photon irradiations. The dose equivalent at a depth of 1 g/cm^2 in the ICRU sphere was calculated along with the dose equivalent at a depth of 1 g/cm^2 in a PMMA dosemeter placed on the face of a 30 x 30 x 15 cm PMMA phantom. This approximates the recommendation given by the ICRU for a dosemeter to be covered with an appropriate amount of tissue equivalent material and calibrated on a suitable phantom (ICRU, 1988). The front face of the phantom was placed at a distance of 100 cm from point sources of radiation that were used to simulate the actual irradiation conditions. Similar calculations were performed with the ICRU sphere as a phantom.

Backscatter factors were measured with thermoluminescent dosimeters ^{7}LiF (TLD-700) chips placed either on the surface of a PMMA slab phantom or on a thin water filled plastic sphere that was 30-cm in diameter. Corresponding measurements at the same reference distance were made with the TLD mounted free-in-air (Large, et al.,1990). Results of the measurements and calculations are shown in Table 1. For dosemeters sensitive to backscatter, these results could be used to correct the air kerma to directional dose equivalent, H'(10), conversion factors. These data also compare favorably to the recent calculations of Bartlett, et al. (1991).

The calculations for neutron irradiations used the larger 40 x 40 x 15 cm PMMA phantom required by the accreditation programs (DOE,1986, ANSI, 1983). The front face of this phantom was placed at 50 cm from the radiation sources. A dosemeter was again mounted on both the surface of this phantom and on the ICRU sphere. The dose equivalents at a depth of 1 g/cm^2 in the ICRU sphere and at the same depth in the dosemeter were calculated. The results of these calculations are shown in Table 2. The present results are within the expected uncertainties of previously reported calculations of conversion factors between fluence and H'(10). Confirmatory measurements are planned for the neutron irradiations using TLD-albedo dosemeters and CR-39 plastic track-etch dosemeters.

CONCLUSIONS

The process of relating the response of dosemeters, calibrated in terms of metrological quantities, to the operational or limiting quantities can be accomplished by the use of appropriate conversion factors. It is also possible to calibrate dosemeters on the rectangular solid PMMA phantoms required by the U.S. accreditation programs, and to relate the response of such dosemeters to the ICRU operational quantities. The conversion factors given in this report were calculated by the Monte Carlo code MCNP and compared to measurements taken with TLD's. The agreement obtained between these two methods was within the expected uncertainties for them. Future work will include the verification of the neutron conversion factors by experimental measurement.

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Table 1. Calculated and Measured Ratios of Photon Backscatter Factors for the 30 x 30 x 15-cm PMMA phantom relative to the ICRU sphere.

Photon Energy (keV)	Calculated BSF Ratio	Measured BSF Ratio
10	1.0	-
20	1.05	0.98
30	1.13	1.19
40	1.23	1.22
50	1.29	-
60	1.26	1.27
80	1.26	1.19
100	1.17	1.06
200	1.09	-
300	1.05	-
662	1.03	1.06
1250	1.02	1.03

Table 2. Calculated Fluence to Directional Dose Equivalent Conversion Factors for Dosemeters Irradiated on the 40 x 40 x 15-cm PMMA phantom and the ICRU sphere. Values are given in terms of pSv/cm^2 (Hertel and McDonald, 1991).

Neutron Energy (MeV)	PMMA Phantom	ICRU Sphere
0.001	6.1	6.2
0.1	66.6	67.1
1.0	361	375
D_2O Moderated ^{252}Cf	87.8	93.2
Unmoderated ^{252}Cf	332	343

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