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Estimation of Radiation Exposure to Workers in Laboratory Accidents

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1. Introduction

The evaluation of the dose to the skin has not been a simple matter. For the most of radionuclide contaminants of concern, the dose to skin consisted of electron and photon. The contributions to the skin dose of these types of radiation depended on their energy distributions and the attenuation of the contamination. Radiation measurement instruments such as survey meters or personal dosimeters did not provide any useful information in the cases of accidents. It was therefore imperative to provide tolerable assessment of skin dose in case any worker accidentally got exposed. Previous studies of skin dose were mostly performed using computational dosimetry codes such as VARSKIN code and Monte Carlo simulations, but there has been rarely performed using laboratory data [1,4]. Exposure of hands and fingertips to relevant dose rates has been of great interest in the presence of high or moderate activities in university laboratories where operational radiation protection has not been usually optimized in terms of manipulation shields, tools and procedures. Radiation safety officers were therefore needed to estimate the potential exposure of given amounts of radionuclides and to assess skin doses from abnormal exposures that might occur under emergency situations. The objective of this study was to estimate skin dose, eye dose and equivalent dose to the occupational worker of Secondary Standard Dosimetry Laboratory (SSDL) of Nuclear Energy Commission (NEC) in Mongolia.

2. Methods and Methods

2.1 Varskin code

The VARSKIN computer code was intended as a tool for the calculation of tissue dose at various depths as the result of skin contamination. Especially, skin dose at 0.07 mm and dose at a depth of 10 mm [5,6]. The contamination was assumed to be a point, disk, cylinder, spherical and slab source located directly on the skin. Source activity was assumed to be evenly distributed throughout the area or volume of all source geometries.

2.2 Irradiation of TLD

Irradiations of TLD were performed by ^{137}Cs source with G10 gamma beam irradiator as shown in Fig. 1. The irradiator was used in SSDL where a source to detector distance (SDD) was 200 cm.

Fig. 1. ^{137}Cs source with G10 gamma beam irradiator.

The beam profile of the gamma irradiator model G10 shown in Fig. 2 were measured by the Physikalisch-Technische Werkstätten (PTW) M32002 reference chamber. The energy response of PTW M32002 chamber could measure the energy within the range of 45 keV to 1.3 MeV.

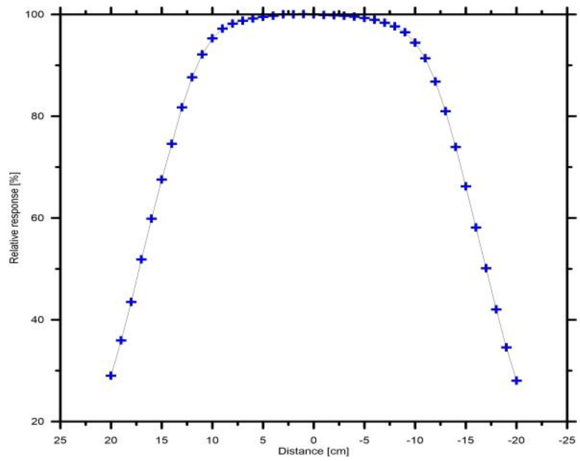

Fig. 2. Beam profile of G10 gamma beam irradiator

With SDD of 200 cm, the TLDs were irradiated in a water phantom of 30 cm×30 cm×15 cm made by PTW as shown in Fig. 3. The irradiated TLDs available for this study were TLD-100 chips (Harshaw-4500) with dimensions of 3.2 mm×3.2 mm×0.89 mm. The time intervals between irradiation and reading were 3 days [3].

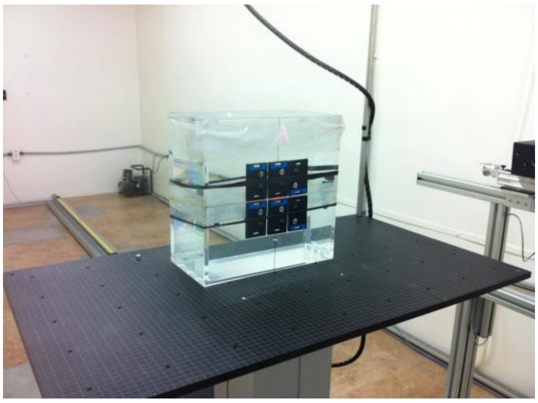

Fig. 3. Irradiation of TLD.

For the use of VARSKIN code, the air gap was limited to a maximum of 20 cm. In this study, air gap was selected as 20 cm from the point source of maximum limit. TLDs were irradiated at 200 cm from the radiation source of ^{137}Cs. Using the inverse square law, the radiation dose at 20 cm from a point source was calculated using Eq. (1).

$$\dot{D}_1 X_1^2 = \dot{D}_2 X_2^2 \qquad (1)$$

where D and X are dose rate and distance to the point of interest, respectively. From Eq. (1), radiation dose at 20 cm was compared with that calculated by VARSKIN code.

3. Results and Discussion

In this study, after the irradiation of TLD measurements were performed by Harshaw 4500 reader in Radiation Control Laboratory (RCL) of General Agency for Specialized Investigation (GASI) in Mongolia. The results showed that there were no appreciable differences between measured data and calculated doses by VARSKIN code. TLDs were used to verify the dose calculation model in different time intervals.

Table I: TLD measurements and personal dose equivalent Hp(10) using VARSKIN

Isotope	Activity (Bq)	Time intervals (s)	Hp(10) (mSv)		Ratio
			TLD	Varskin	
^{137}Cs	7.4×10^{11}	242.12	107.0	109.8	0.97
		605.30	260.0	274.8	0.95
		1210.60	534.0	548.4	0.97
		2421.21	1048	1098	0.95
		6053.02	2602	2748	0.95

Differences between calculated and measured doses were found to be within 2.6% for different time intervals. These findings confirmed that the model adequately described the experiment. Table I showed results of personal dose equivalent of TLD measurements and dose calculations for the purpose of comparison [2]. Results between measured and calculated values using VARSKIN were in good agreement. The agreement in the case of personal dose equivalent was shown in Fig. 4.

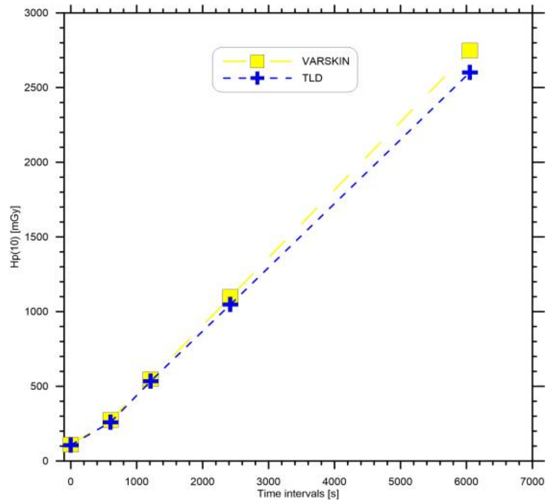

Fig. 4. Comparison between TLD and VARSKIN.

Doses of VARSKIN were converted from mGy/h to nGy/min. The dose rates were specific to the defined source strength, geometry, skin depth, source covering area and radius. Fig. 5 showed a rapid increase in dose at the shallowest of depths due to increasing population of charged particles creating build up before electronic equilibrium was reached.

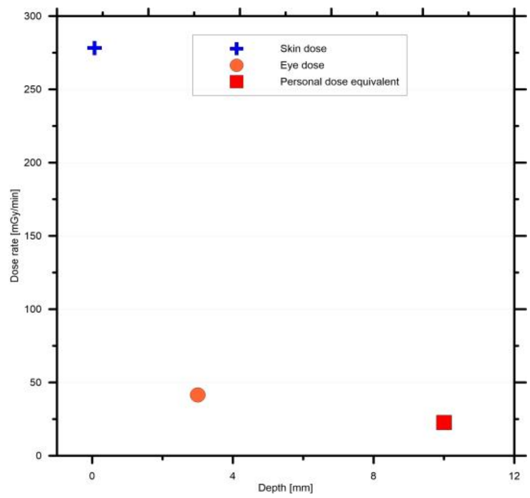

Fig. 5. Dose rate as a function of depth from ^{137}Cs source.

Electronic equilibrium occurred at about 0.07 mm, and then dose decreased with increase with depth. A depth interval of skin dose, eye dose and equivalent dose were considered. Especially, at the skin depth of 0.07 mm, dose rate was 7~12 times higher than the depth of 3 mm and 10 mm. This high value could be explained as a result of dose contributions from the electron on the surface of skin. Additionally, calculation results showed that the exact dose contributor to the skin could be differentiated between photon and electron dose.

3. Conclusions

VARSKIN code was a useful tool for estimating skin dose at 0.07 mm, eye dose at 3 mm and personal dose equivalent at a depth of 10 mm. We compared the results of TLD measurements and VARSKIN calculations for a point geometry of ^{137}Cs radiation source. We found good comparison results between TLD measurements and calculations using VARSKIN code for the case of one-dimensional source model in terms of personal dose equivalent Hp(10). The deviations between calculated and measured doses were within the range of 2.6% for different time interval measurements. Calculation results showed that values of directional dose equivalent H'(0.07) were 7~12 times higher than eye and personal dose equivalent Hp(10) which was dose rate over area of 1 cm^2. Calculation results could give more precise results in a reasonable time and improve the accuracy of assessing skin doses in routine as well as accidental exposure. Even in cases of laboratory accidents, it was found that occupational radiation doses to laboratory workers by the unexpected exposures could be assessed using VARSKIN.

Acknowledgements

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