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Ultrathin TLD Measurement of Alpha Dose-rate and Comparison with Alpha Counting

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INTRODUCTION:

Determination of internal beta dose-rates in pottery using thermoluminescence dosimeters (TLD) has been reported (e.g., Mejdahl (1978), Wang (1982a), Bailiff and Aitken(1980)). This article describes the measurement of internal alpha dose-rates in pottery using $CaSO_4$:Tm ultrathin thermoluminescence dosimeters. Among the advantages of the technique are convenience and low cost.

METHOD:

The ultrathin $CaSO_4$:Tm dosimeters (thermoluminescence dosimeter type II) are manufactured by the Shanghai Industrial Hygiene Institute (Zhou, 1982). Phosphor is deposited onto 8 mm diameter, 10 micron thick aluminum foil to a thickness of 2 mg/cm^2. For each pottery sample twelve TLDs are annealed at 400 degrees C for five minutes then divided into two groups of six - Groups A and B. Group A dosimeters are as described above and, therefore, are alpha-shielded on only one side. Group B dosimeters have an additional top covering of foil and are, therefore, completely shielded against alpha particles.

Four dosimeters from each group (a total of eight) are embedded in a glass container of powdered pottery (fig. 1). The remaining four dosimeters are deposited in either quartz or $CaSO_4$ (both low radioactivity) to measure environmental radiation. Containers are sealed and stored in the dark for at least one month. At the end of the storage period, the dosimeters are removed, cleaned in distilled water and dried at about 80 degrees Centrigrade.

The TL of Group B dosimeters derives from beta and environmental radiation only while Group A dosimeters produce TL resulting from an additional alpha particle dose. However, since the Group A dosimeters are alpha-shielded on one side, their alpha contribution results from one-half the infinite matrix alpha dose-rate. The thermoluminescence induced by 4-Pi geometry alpha irradiation, G_α, is obtained by the equation

$$G_\alpha = (G_a - G_b) \times 2$$

where G_a is the average TL of Group A dosimeters and G_b is the average TL of Group B dosimeters in the sample. Although not rigorously correct, it is assumed in the calculation that the phosphor thickness is small compared to the alpha particle range. The alpha dose-rate, D_α, is

$$D_\alpha = G_\alpha / (\chi_\beta \cdot \varepsilon \cdot t)$$

where χ_β is the TLD beta sensitivity,

t is the storage time and

ε is the ratio of alpha to beta sensitivity (0.15 for this phosphor).

The beta dose-rate, D_β, for the sample can also be obtained from the measurements as

$$D_\beta = (G_b - G_c)/(\chi_\beta \cdot t)$$

where G_c is the average TL of the environmental dosimeters.

RESULTS:

The results of alpha TLD measurements on 28 samples are shown in Table 1. Also shown are the results of alpha counting measurements on the same samples using a surface barrier detector (Aitken, 1978; Wang, 1981). Measurement error is less than 7% for TLD and less than 3% for alpha counting. It can be seen that there is reasonable agreement between TLD and alpha counting in most cases. For samples showing large discrepancies the TLD results are systematically higher. Since alpha counts were performed unsealed and TLD accumulations were sealed, it is thought that these differences may result from differences in radon retention for the two methods. In the case of the pottery body itself, we have found the probability of radon escape to be less than 10% (Wang, et al., 1982b). The samples should be sealed in the containers during the TLD measurement to duplicate the situation during burial.

TABLE 1

Comparison of annual alpha dose by TLD and alpha counting

Laboratory Reference	Dose-rate (rad/yr) TLD	Alpha counting	TLD/Alpha
SML 1a	3.040	2.668	1.14
2a2	3.755	3.703	1.01
2a3	3.173	3.268	0.97
7a	2.835	2.555	1.11
7b	2.916	2.770	1.05
9a	2.067	2.156	0.96
17	2.027	2.188	0.93
19a1	2.307	2.474	0.93
25b	3.606	3.572	1.01
25c	3.594	3.099	1.16
25e	3.183	3.288	0.97
27b2	4.315	4.109	1.05
27c1	4.147	3.989	1.04
27c2	3.933	2.715	1.45
28b	4.015	3.660	1.10
28c	4.762	4.905	0.97
28d	4.751	4.479	1.06
28e	3.793	4.012	0.95
37a	5.350	5.115	1.05
37b	4.670	4.431	1.05
37c	4.662	4.289	1.09
38a	4.588	4.571	1.00
39a	6.497	6.252	1.04
39b	7.263	6.630	1.10
40a	4.720	4.802	0.98
41a	5.133	3.660	1.40
42a	2.587	2.452	1.06

CONCLUSIONS:

We have demonstrated that it is possible to measure internal alpha dose-rates in pottery using ultrathin TLD and have found the results to be in reasonable agreement with alpha counting. The TLD method has the advantages of low cost and convenience. In addition, some correction for water content and disequilibria is accomplished.

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Figure 1: Irradiation Configuration for Ultrathin TLD Determination of Alpha Dose-rate