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ABSTRACT

The energy dependence of $CaSO_4$:Dy, $CaSO_4$:Tm and LiF-7 TLDs was investigated. For $CaSO_4$ TLDs the performance criteria laid down by ANSI cannot easily be fulfilled. In environmental monitoring applications, special care must be paid to the selection of the filter material for $CaSO_4$:Dy or $CaSO_4$:Tm.

АННОТАЦИЯ

Исследовалась энергетическая зависимость термолюминесцентных дозиметров $CaSO_4$:Dy, $CaSO_4$:Tm и LiF-7 от различной толщины фильтров. Критерии, предлагаемые ANSI /Американский госкомитет по стандартам/, в случае ТЛД $CaSO_4$ простым путем не выполняются. Поэтому при дозиметрических измерениях, проводящихся с целью контроля окружающей среды, нужно обращать особое внимание на выбор фильтров.

KIVONAT

Megvizsgáltuk a $CaSO_4$:Dy, a $CaSO_4$:Tm és a LiF-7 TLDk energiafüggését különböző vastagságu szürők alatt. Az ANSI, az Amerikai Szabványügyi Hivatal által javasolt kritériumok nem teljesithetők egyszerü módon a $CaSO_4$ TLD-k esetén. A környezeti dozimetriai mérések végzésekor emiatt különös figyelmet kell forditani a $CaSO_4$:Dy vagy a $CaSO_4$:Tm szürőanyagának kiválasztásakor.

INTRODUCTION

$CaSO_4$:Dy TLDs found an application in environmental monitoring because of their great sensitivity to gamma radiation. In that the thermoluminescent signals of our $CaSO_4$:Dy dosimeters submitted to the 3rd International Intercomparison of Environmental Dosimeters, Houston, 1977, differed by a factor of two because of the different capsules used, our attention was called to the energy dependence of $CaSO_4$:Dy under different filters. In view of this, it was decided to investigate the energy dependence of $CaSO_4$:Dy, $CaSO_4$:Tm and LiF-7 TLDs.

The aim of the present work is to call attention to the energy dependence problem of environmental dosimeters because many of the environmental dosimeters used today do not fulfil the criteria laid down by ANSI /N545-1975/ for environmental applications [1].

EXPERIMENTAL

In the energy dependence measurements, the following TLDs were used: $CaSO_4$:Dy, LiF-7 powders /Harshaw Chemical Co./; $CaSO_4$:Dy Teflon discs /Teledyne Isotopes, Ø: 12.7 mm x 0.4 mm, phosphor content in Teflon is 30 weight %/; and $CaSO_4$:Tm /made by one of the authors - J.F/. The $CaSO_4$:Tm had a grain size of 0.1 - 0.2 mm and a Tm content of 0.17 mol%. Before use the $CaSO_4$ powders were annealed at 400 ^{o}C for 0.5 h, the Teflon discs at 260 ^{o}C for 6 h, the LiF-7 powder at 400 ^{o}C for 1 h and subsequently at 100 ^{o}C for 2 h. The powders were portioned out by a vibrating powder dispenser /Teledyne Isotopes/ with an accuracy ± 1.5%. The TL measurements were carried out on a TLD reader of our own manufacture [2], which has an EMI 9844B photomultiplier tube /PMT/ with low dark current. The temperature of the PMT is

kept constant by a thermoelectric cooler. The heating profile is linear; the heating parameters can be varied over a wide range. The TLDs were heated to 300 ^{o}C in 30 s and the measuring of the TL light started when the temperature of the heating pan was higher than 160 ^{o}C; this was done to eliminate any short term fading. The sensitivity of the TLD reader was checked during the TL measurements by a built-in standard light source and was found to be constant within the limits of ± 1.5%. At each photon energy and for each shielding capsule, 5 or 7 TLD samples were irradiated and measured. The empirical standard deviation of the TL measurements was around 2-3% for the powders, and 5-7% for the Teflon discs. Cylindrical capsules were used for the TLD powders with an inner diameter of 5 mm; the outer diameter varied according to the wall thickness. 3 Teflon discs were put into an aluminium capsule of 2 mm wall thickness in between 1 mm thick Bakelite plates.

The irradiations were performed in the laboratory of the Hungarian National Office of Measures /OMH/ on an X-ray machine /Isovolt 400 kV, Rich, Seifert Co./ and with ^{137}Cs and ^{60}Co isotopes. The quality of the radiation was selected in accordance with the BIPM recommendation [3]. The exposure was measured with an accuracy of 2% by an ionization chamber calibrated several times in international intercomparisons by OMH [4,5]. During the irradiations the absorbed dose in air was 10 mGy for LiF-7 and 5 mGy for the $CaSO_4$ TLDs.

RESULTS AND DISCUSSION

The energy dependence under different filters is shown in *Fig. 1*, for $CaSO_4$:Dy Harshaw powders, the numerical values are found in *Table 3*. Each point or number represents the mean value of the TL signals of the 5 or 7 dosimeter samples. It can be seen that the energy response of $CaSO_4$:Dy is flat between the limits of 20% from 120 keV only in the Sn 1.6 mm capsule. Even this filtration did not fulfil the requirements of the performance criteria for environmental dosimeters [1], because the

energy dependence can be less than 20% in the range of 80 keV - 3 MeV, and can differ by a factor of 2 below 80 keV.

This means that for the environmental application of $CaSO_4$ TLDs special attention must be paid to the selection of the filter material and its wall thickness. Correct results can be obtained if the $CaSO_4$ TLDs are used in tandem as was proposed by Pradhan and Bhatt [6]. In this way an energy independent response can be obtained, and the energy of the radiation can also be estimated.

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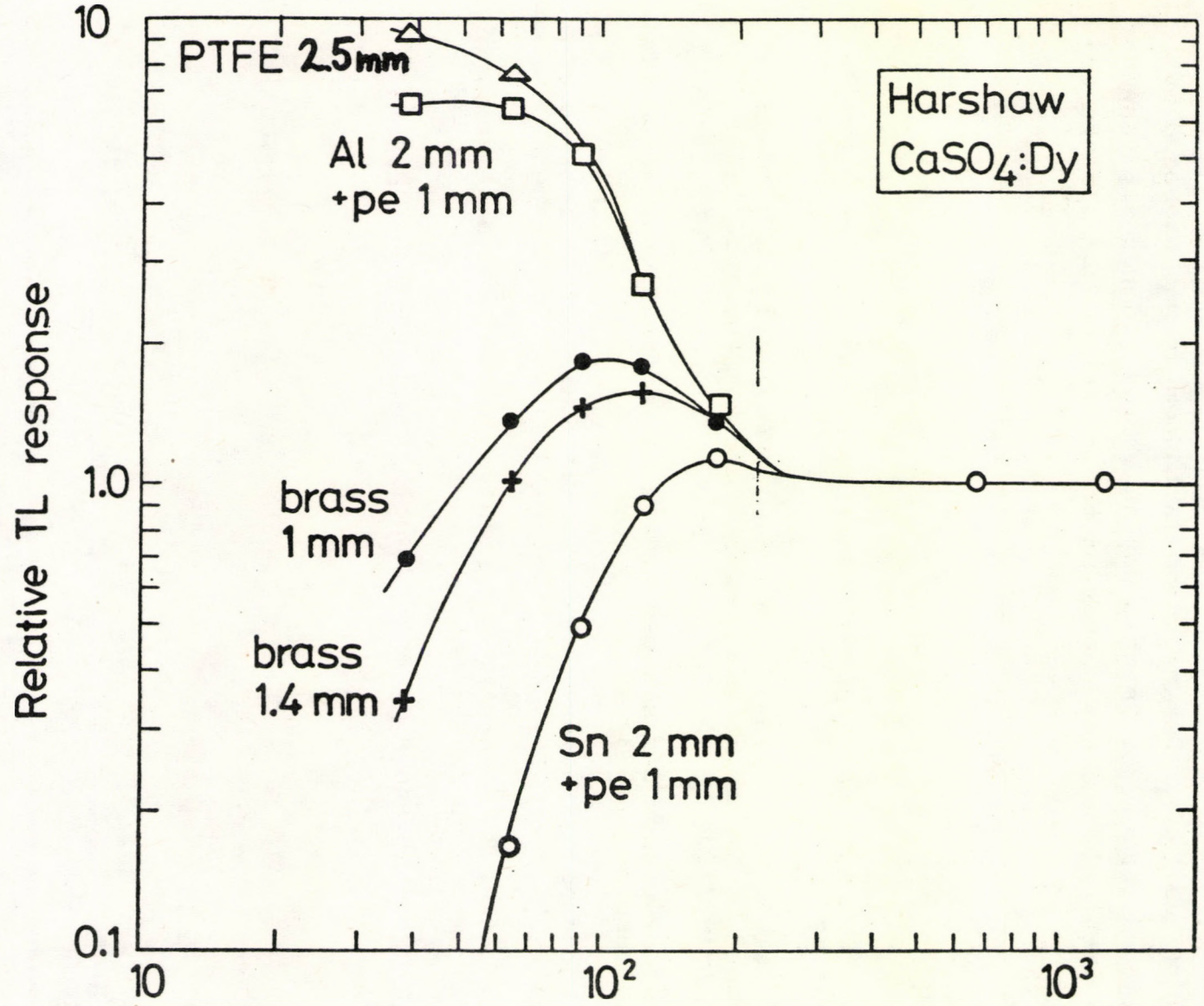


Fig. 1. Relative TL response of the $CaSO_4$:Dy powder under different filter materials. The density of the brass was 8.2 g.cm^{-3}. "pe" - polyethylene

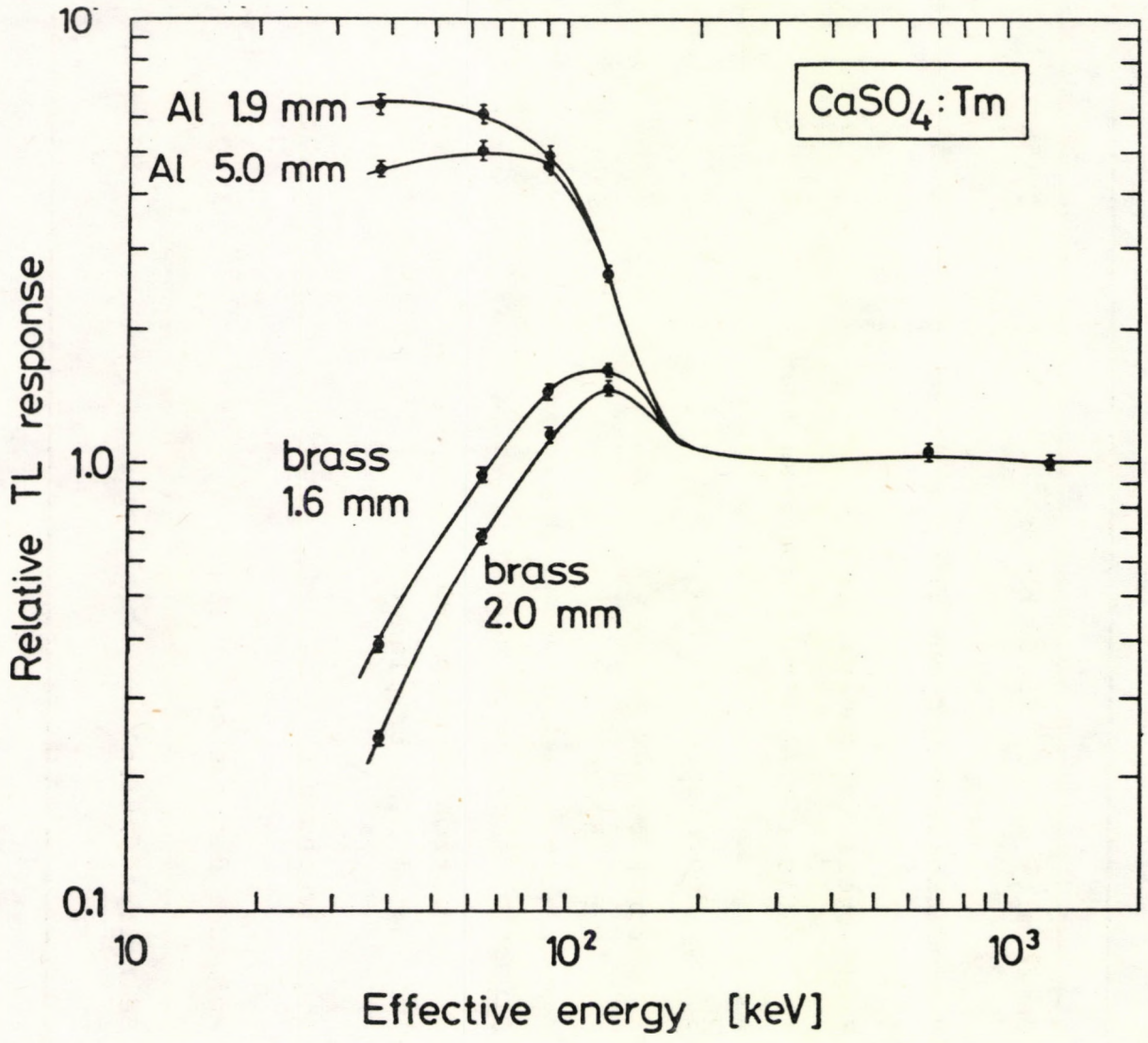


Fig. 2. Relative TL response of the $CaSO_4$:Tm powder under brass and aluminium filters

Table 1

TLD performance criteria for environmental application
/ANSI N545-1975/

Uniformity within field batch [1]	± 15%
Reproducibility for one TLD [1]	± 5%
Field cycle interpretation [2]	
ratio I(t)/2xI(t/2) not less than	0.9
Energy dependence /30 keV - 3 MeV/	
for > 80 keV	⩽ 20%
for < 80 keV	factor 2
Direction dependence during rotation through two perpendicular planes	± 10%
Light dependence [2]	⩽ 10%
Moisture dependence [2]	⩽ 10%
Self irradiation [2]	⩽ 10 µR/h

[1] for an exposure rate of 10 µR/h during field cycle and at the 95% confidence level

[2] for a period t equal to the field cycle

Table 2

Radiation quality of the X-ray irradiations
/The inherent filtration is 0.5 mm Cu/

Tube tension / kV /	Filtration / mm /	Photon energy / keV /	HVL /mm Cu/
100	1 Al	38	0.15
135	0.1 Cu 1 Al	64	0.5
180	0.35 Cu 1.0 Al	91	1.0
250	1.55 Cu 1.0 Al	123	2.5
350	7.0 Cu 1.0 Al	180	4.5

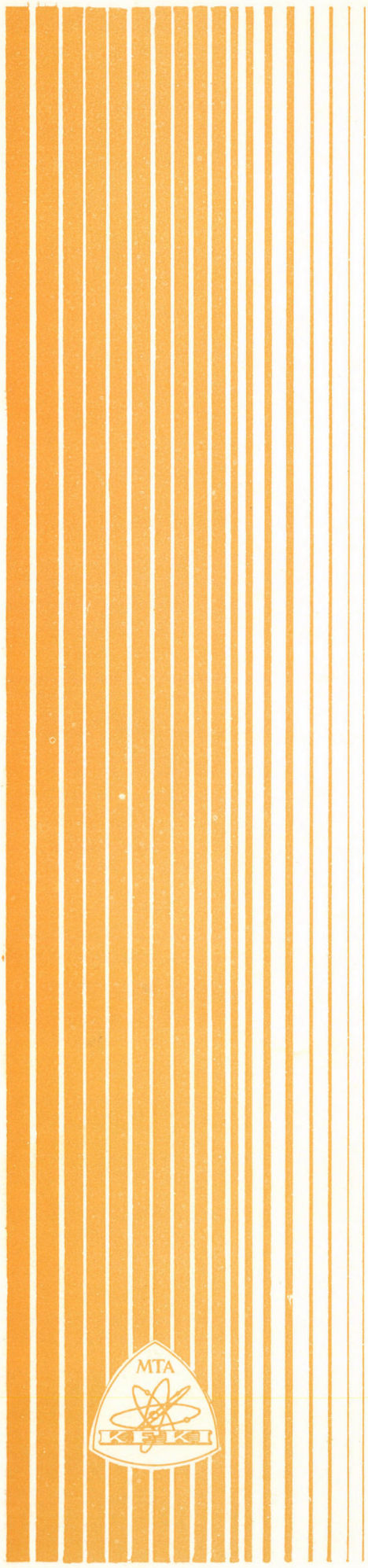
Table 3

Relative TL responses of $CaSO_4$ and LiF-7 TLDs under different filter materials.
Standard deviation of TL measurements: 3% for TL powders; 7% for Teflon discs

TLD	Wall thickness /mm/ of capsule material	Effective photon energy /keV/						
		38	64	91	123	180	660	1250
$CaSO_4$:Dy Harshaw powder	2.5 PTFE + 1 pe	9.26	7.59	5.48	2.74	1.47	1.01	1.00
	2 Al + 1 pe	6.57	6.45	5.06	2.68	1.46	1.01	1.00
	1 brass /8.2gcm^{-3}/	0.70	1.37	1.81	1.79	1.36	1.02	1.00
	1.1 brass	0.54	1.35	1.75	1.80	1.37	1.06	1.00
	1.2 brass	0.49	1.25	1.77	1.82	1.41	1.05	1.00
	1.3 brass	0.41	1.10	1.51	1.59	1.35	1.02	1.00
	1.4 brass	0.35	1.02	1.47	1.59	1.38	1.02	1.00
	1.6 Sn + 1 pe	0.05	0.17	0.49	0.90	1.12	1.01	1.00
	3 Bakelite + 1 pe	7.08	6.67	5.13	2.73	1.47	1.03	1.00
	3 Bakelite + 0.5 Cd + + 0.5 Al + 1 pe	0.67	1.11	1.60	1.70	1.35	1.02	1.00
	3 Bakelite + 2 Al + 1 pe	7.06	6.45	5.17	2.79	1.50	1.05	1.00
	3 Bakelite + 0.6 Sn + + 0.5 Al + 1 pe	0.70	1.21	1.70	1.78	1.40	1.03	1.00

Table 3 /continued/

TLD	Wall thickness /mm/ of capsule material	Effective photon energy /keV/						
		38	64	91	123	180	660	1250
$CaSO_4$:Tm	1.9 Al	6.43	6.13	4.96	2.63	-	1.08	1.00
powder	3.0 Al	5.53	5.92	4.90	2.67	-	1.09	1.00
	5.0 Al	4.57	5.00	4.69	2.67	-	1.09	1.00
	1.6 brass	0.39	0.94	1.44	1.61	-	1.07	1.00
	1.8 brass	0.32	0.84	1.34	1.52	-	1.08	1.00
	2.0 brass	0.25	0.69	1.15	1.47	-	1.07	1.00
$CaSO_4$Dy disc	2.0 Al + 1.0 Bakelite	5.24	4.83	3.52	1.95	-	0.99	1.00
LiF-7	1.2 Al	1.03	1.07	1.09	1.04	-	0.99	1.00
Harshaw	1.4 Al	1.00	1.09	1.09	1.07	1.00	1.02	1.00
powder	1.6 Al	0.92	1.09	1.10	1.03	0.98	1.03	1.00
	1.8 Al	0.96	1.08	1.09	1.05	1.05	1.04	1.00
	1.95 Al	0.89	1.06	1.08	1.05	1.01	1.01	1.00
	3.0 Al	0.83	1.00	1.11	1.09	1.03	1.01	1.00
	5.0 Al	0.67	0.94	1.06	1.08	1.02	1.00	1.00
	0.5 brass	0.36	0.67	0.96	1.08	-	1.04	1.00
	0.65 brass	0.23	0.67	0.78	1.06	-	1.00	1.00



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