Response of current environmental dosemeters to new operational quantities

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In response to the new ICRU Report 95 [1], released last year, currently used dosemeters were tested in laboratory conditions. The Report presents the new system of operational quantities for external radiation. Before implementing of the new quantities as legally binding, instruments must be adapted to measure them adequately. To analyse the performance of current dosemeters, they were exposed to different photon or neutron spectra. Measured values were compared with reference values expressed in old and new quantity. This study was focused on environmental active survey monitors and passive thermoluminescence (TL) dosemeters. They were mostly adapted to measure ambient dose equivalent (H*(10)) or directional dose equivalent (H'(0.07)). The new quantities that will replace these quantities are ambient dose (H*) and directional absorbed dose to local skin ($D'_{local\ skin}$) [1]. The differences are indicated below.

Laboratory experiment

Dosemeters were irradiated to reference values of air kerma or fluence (neutron dosemeter) using various radiation spectra [2]. With a help of conversion coefficients [3, 1], reference values H^*_{ref} and $D'_{local\ skin\ ref}$ were assessed. Measured $H^*(10)_m$ was compared with the reference value H^*_{ref}. In the case of dosemeters calibrated by the user, ratios H^*_m/H^*_{ref} and $D'_{local\ skin\ m}/D'_{local\ skin\ ref}$ were calculated.

Tested dosemeters

Active photon dosemeters, passive photon dosemeters and active neutron dosemeter

Dosemeter	Manufacturer	Detector	Measured quantity
RT-30 G Super Ident	Georadis	NaI(Tl), GM	K_a, H*(10), X and their rates
GR-135 Plus	SAIC Exploranium	NaI(Tl), GM	K_a, H*(10), X and their rates
RadEye PRD-ER	Thermo Scientific	NaI(Tl)	Ḣ*(10), H*(10)
RadEye G-10	Thermo Scientific	GM	Ḣ*(10), H*(10)
U-RAD 115	Canberra	GM	Ḣ*(10), H*(10)
SPIR-Ace	Mirion Technologies	$LaBr_3$(Ce), GM	Ḣ*(10)
NuEM Drones G	NUVIA	NaI(Tl), GM	K_a rate
bGeigie Nano	SAFECAST	GM	Ḣ*(10)
Mob-DOSE	Pico Envirotec Inc.	2x GM	K_a and its rate
NuDET EGM-02	NUVIA	2x GM	Ḣ*(10)
Harshaw 8855	Thermo Scientific	^{7}LiF:Mg,Cu.P	H*(10), H'(0.07)
Rados	Mirion Technologies	Al_2O_3:C	H*(10)
LB 6411	Berthold Technology	^{3}He	Ḣ*(10)

Results

Dosemeter		$\dot{H}^*(10)_m/\dot{H}^*_{ref}$							
		N-80	N-100	N-120	N-150	N-200	N-300	S-Cs	S-Co
NuDET EGM-02	GM1	0.838	0.833	0.936	1.054	1.107	0.873	1.01	-
	GM2	1.343	1.121	1.05	1.16	1.378	1.287	1.206	1.317
RT-30 G	NaI(Tl)	0.77	0.828	0.788	0.835	0.987	1.062	1.245	-
	GM	0.789	0.736	0.83	0.938	0.998	0.916	1.325	1.46
GR-135 Plus	NaI(Tl)	0.76	0.932	0.979	-	1.63	1.236	1.245	-
	GM	0.739	0.683	0.73	0.802	0.895	0.822	1.098	1.383
SPIR-Ace	$LaBr_3$(Ce)	1.1	1.091	1.11	1.034	1.04	0.896	1.194	-
	GM	1.165	1.071	1.091	1.134	1.121	0.999	1.141	1.464
RadEye PRD-ER		0.891	1.394	1.994	2.537	3.193	2.405	1.375	1.023
RadEye G-10		1.598	1.461	1.362	1.371	1.24	1.075	1.173	1.539
U-RAD 115		1.098	1.331	1.461	1.495	1.275	0.988	1.167	1.397
bGeigie Nano		3.762	2.69	2.257	1.839	1.37	0.962	1.162	-

Dosemeter		$\dot{H}^*_m/\dot{H}^*_{ref}$							
		N-80	N-100	N-120	N-150	N-200	N-300	S-Cs	S-Co
MobDose	GM1	0.974	0.872	0.839	0.928	1.64	1.353	1	1.048
	GM2	0.934	0.792	0.755	0.854	0.972	0.863	1	1.603
NuEm Drones (GM)		0.709	0.79	0.888	1.001	1.007	0.852	1	1.359

Dosemeter	H^*_m/H^*_{ref}								
	N-80	N-100	N-120	N-150	N-200	N-250	N-300	S-Cs	S-Co
Harshaw 8855	1.129	0.985	0.918	0.957	1.068	1.051	1.036	1.038	1.082
Rados	1.532	1.129	0.945	0.882	0.831	0.86	0.88	1.035	1.044

Dosemeter	$D'_{local\ skin}(0°)_m/D'_{local\ skin}(0°)_{ref}$						
	N-80	N-100	N-120	N-150	N-200	N-250	N-300
Harshaw 8855	0.805	0.748	0.723	0.751	0.829	0.876	0.989

Dosemeter	$\dot{H}^*(10)_m/\dot{H}^*_{ref}$						
	thermal	^{252}Cf + 6"PE	^{252}Cf + 4"PE	^{252}Cf + 3"PE	^{252}Cf	^{241}Am-Be	generator
LB 6411	1.23	1.24	1.24	1.2	1.09	0.94	0.65

Discussion and conclusion:

The new operational quantities are designed to better correspond to a human body, so they provide less conservative estimates of protection quantities than the old quantities. This brings discrepancies also into practice measurement. The response in relation to H* was higher. It was revealed that there is almost a constant difference between the response related to the old or to the new quantity in the photon energy interval mostly relevant for area monitoring. Therefore, the application of a correction factor, to adapt a dosemeter's response to the new quantity, would be appropriate. In the case of kerma rate meters or passive dosemeters, calibration can be done by the user with a help of the published conversion coefficients. For the purposes of very low-energy spectra measurements, further tests should be done. TLD Harshaw 8855 would need the optimization of calculation algorithm to measure correctly $D'_{local\ skin}$. The energy response of neutron dosemeter changed but it still met the standardized limits.

[1] ICRU, 2020. Operational quantities for external radiation exposure. ICRU Report 95.

[2] ISO, 2019. Radiological protection- X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy- Part 1: Radiation characteristics and production methods. ISO 4037-1.

[3] Otto, T., 2019. Response of photon dosimeters and survey instruments to new operational quantities proposed by ICRU RC26. J.Instrum. 14, P01010.

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