Australian Journal of Basic and Applied Sciences, 10(7) Special 2016, Pages: 30-33

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

Performance Evaluation on Three OSLD Readersin the Dose Range of 1- 10 mSv

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ARTICLE INFO

Article history:
Received 10 January 2016
Accepted 15 February 2016
Available online 28 February 2016

Keywords:
OSLD reader Linearity
Accuracy OSLD

ABSTRACT

Background: In the past six years, the SSDL laboratory of Nuclear Malaysia Agency has been using the microStar reader (labelled here as R1) to get the OSLD readings. Recently, the laboratory acquired two new readers, Auto 200 (R2) and Auto 500 (R3).**Objective:** The purpose is to evaluate the performance on the two new readers in comparison with the existing one. Two tests were utilised for five delivered doses namely 1, 3, 5, 7 and 10 mSv: (a) for the linearity test, i.e. the graph of$y$=D_{meas}(measured dose) versus$x$=D_{del} (delivered dose)was plotted for each reader. The experimental straight-line gradients m_{R1}, m_{R2} and m_{R3} (respectively for reader R1, R2 and R3) were compared with the theoretical gradient $m_t$of which m_t=1 and c=0 in the equation of $y=m_t x+c$; (b) for the accuracy test using the trumpet graph as suggested by the ICRP 1991, the experimental value for the five dosesi.e. R_{1mSv}, R_{3mSv}, R_{5mSv}, R_{7mSv}, and R_{10mSv}should respectively lie in the range of $0.55 \leq R_{1mSv} \leq 1.63$, $0.62 \leq R_{3mSv} \leq 1.55$, $0.64 \leq R_{5mSv} \leq 1.53$, $0.65 \leq R_{7mSv} \leq 1.52$, and $0.65 \leq R_{10mSv} \leq 1.51$.$R$ is the ratio of the D_{meas} to D_{del}.**Results:**For the first test,m_{R1}, m_{R2} and m_{R2}were found to be 0.989, 0.939 and 1.035. In percentange deviation of the gradient Δ_m(%) (compared to the theory) this is equal to −1.1%, −6.1% and 3.5%. If the evaluation is solely based on this test, it looks as if only R1 is suitable for use as it yielded Δ_m(%) less than ±1.5%. However when the second test were taken into account, it was found that all the three readers are suitable for use as they fulfilled the test requirement.**Conclusion:**Since the two new readers passed the accuracy test, the laboratory decided to use these readers in addition to the existing microStar reader.

To Cite This Article: W.N.S.W. Ikmal., N.F. Muhamad and S.B. Samat., Performance Evaluation on Three OSLD Readers in the Dose Range of 1- 10 mSv. ***Aust. J. Basic & Appl. Sci.,*** *10(7): 30-33, 2016*

INTRODUCTION

Secondary Standard Dosimetry Laboratory (SSDL) at Malaysia Nuclear Agency had been responsible in quality assurance of dosimeters. OSLD was introduced since 2009 in Malaysia to get the measured dose. For readout process, the OSLD reader was used to measure the absorbed dose with rate of 10 seconds for one dosimeter. The OSLD reader operated using an array of 38 green LEDs for the readout process. The stimulation was depended on the range of dose where 38 LEDs used for low doses and only 6 LEDs used for high doses. Usually, the SSDL Malaysia had used microStar reader to get the absorbed dose. Recently, two new readers which were Auto 200 and Auto 500 had been acquired. Both readers had the capacity to measure a total of 200 and 500 units of OSLD respectively.

Reuven (2001) reported that linearity as one of the features of a good detector. Linearity or also known as dose response meansthe ability of the detector to give the same value of absorbed dose asthe given dose. An ideal detector should have a signal that is linearly proportional to the absorbed dose of radiation for a given radiation field (Yukiharaand McKeever, 2011). However, because of the result of the dynamic of the charge captured process between different defects in the material, they predicted that the deviation from the linearity would happen (Yukihara and McKeever, 2011). Somehow in personal dosimetry, especially for dose range from 0.0001 to 10Gy, theyalso stated that it had been reported for the OSL response of Al_2O_3:C was linear over the wide dose range.

Ahmad *et al* (2012) reported on the linearity done for InLight OSLD with dose range from 0.1 to 10.0 mSv by using X-ray and gamma sources. From the values of linear regression coefficient, R^2, it showed that all R^2 is closer to 1. Freire *et al*. (2008) had done the linearity evaluation on LiF detectors of TLD-100 and TLD-100H with the dose values of 1, 2, 5, 10, 20, 50, and 100 mSv by using gamma source of ^{137}Cs and X-ray source of N120. They found that LiF detectors show a linear behaviour and performed well.

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Australian Journal of Basic and Applied Sciences, 10(7) Special 2016, Pages: 30-33

The aim of this study is to evaluate the performance on the two new readers, Auto 200 and Auto 500 in comparison with the microStar reader. This evaluation is based on two tests which are (a) the linearity test and (b) the accuracy test using the ICRP's trumpet graph.

MATERIALS AND METHOD

Three OSLD readers were used. The first one was the microStar reader that only could read one dosimeter at one time. It was 32.7cm x 23.2cm x 10.9cm in size. The other two were Auto 200 reader with dimension 110cm x 46cm x 38cm and Auto 500 reader with dimension 110cm x 49cm x 77cm. All readers yielded the readings of measured dose, D_{meas}fordeep dose, $H_P(10)$ andskin dose, $H_P(0.07)$.However, only the readings of $H_P(10)$ were used. In this study, the readers ofmicroStar, Auto 200 and Auto 500 were labelled as R1, R2 and R3.

This study was done at the Secondary Standard Dosimetry Laboratory (SSDL), Malaysia. A total of eighteen OSLDs were used where fifteen of them were irradiated and three OSLD were acted as controlled OSLD. Each controlled OSLD represented three OSLD readers used in this study. All OSLD to be irradiated, were divided into five groups. Each group had three irradiated OSLDs and each group represented doses used for present study. Before the irradiation process, all the OSLDs were annealed using the InLight 50A Automatic Annealer in order to release all the residue signals left. Each OSLD was annealed for fifteen seconds.

Radionuclide source of gamma ^{60}Co with energy of 1250 keV was used in this study. A few steps were taken before the designated OSLD groups were exposed to specific doses. It was done to calculate the time of irradiation for specific doses. The air kerma, K_a on the experiment day had to be calculated first.

$$K_a = K_{a(ref)} \times e\left(\frac{-\ln 2 \times \Delta T}{t_{1/2(\gamma)}}\right) \quad (1)$$

where$K_{a(ref)}$ was the latest $K_a$that calculated before the experiment day , $t_{1/2(\gamma)}$ was half- life of gamma source and Δt was the periods of times (in days) from $K_{a(ref)}$ was calculated until the day of the experiment.

Time of irradiation, *t* (in second) was then calculated based on the K_a.

$$t = \frac{D_{del}}{K_a \times H_p(10)_{cc}} \text{x60 sec} \quad (2)$$

where $H_P(10)_{CC}$ was the conversion coefficient (in Sv/Gy) from air kerma for $H_P(10)$ and $H_P(0.07)$. For radionuclide source of gamma ^{60}Co, the $H_P(10)_{CC}$ was 1.15 Sv/Gy . The D_{del} was the delivered dose used in this study. The doses were 1, 3, 5, 7 and 10 mSv. The value of *t* might different for every dose as it depends on the $D_{del}$and K_a.

When *t* has been calculated, the OSLDs together with its holder were placed in front of the ISO water slab phantom with dimensions of 30cm x 15cm x 15cmbefore being exposed to the gamma radiation based on the calculated *t*. The distance between the gamma source to the water phantom was five meter. After the irradiation process, all the dosimeters had been stored for a day to stabilize the trapped electron. For readout process, the dosimeters were measured using the three readers. All the steps taken were then repeated for ten times for dose values of 1,3, 5, 7 and 10 mSv in order to get the average readings of $H_P(10)$. The rate of *t*for doses 1, 3, 5, 7 and 10 mSv were 38.95, 114.52, 189.92, 265.53 and 378.86 seconds respectively.

A linear graph of D_{meas}versusD_{del} was plotted to get the linear equation $y=mx+c$. From here, the values of *m*, *c* and R^2were obtained.

Dose measurement accuracy test was done for this study to determine whether the D_{meas}obtained was accurate or not. For this purpose, the ratio of D_{meas} to the D_{del} known as *R*wascalculated. Trumpet graph was used as recommended by ICRP (1991) to determine the accuracy of D_{meas}. The value of *R* should be in the range of lower limits, L_L and upper limit, U_L. The dose was accurate if *R*lied between the U_L and L_L calculated for each dose.The values of U_L and L_L were different for each dose as it depends on the D_{del}.

$$L_L \leq R \leq U_L \quad (3)$$

$$L_L :\left(\frac{1}{1.5}\right)\left[1 - \left(\frac{2D_L}{D_L + D_{del}}\right)\right] \quad (4)$$

$$U_L :(1.5)\left[1 + \left(\frac{D_L}{2D_L + D_{del}}\right)\right] \quad (5)$$

where D_L is the lowest dose can be detected that is 0.1 mSv. D_{del} is the delivered dose.

RESULTS AND DISCUSSION

The $H_P(10)$ of OSLD are measured using three readers as mentioned to get the D_{meas}. The uncertainties are calculated from the D_{meas}. This calculation is applied to every doses and readers. Table 1 shows the $D_{meas}$and the calculated uncertainties from this study for all readers. From Table 1, all the readers give out the readings of D_{meas} closer to the D_{del} with standard error, SE in the range 0.03 to 0.22. The Δ %of D_{meas}R1 is from −3.20 to 0.20%. For reader R2, the values Δ %of the $D_{meas}$is within the range−5.36 to to 0.20 and R3 is given from 1.08 to 7.90%.

Linearity test is done on the D_{meas} obtained from the three readers. A clear result can be depicted through a linear graph. Figure 1 show the linear graph plotted on D_{meas}versusD_{del} for readers R1, R2 and R3 together with the straight-line of gradient. Broken line acts as reference line for the theoretical gradient, m_t is equal to 1.

For Figure 1 (a), it can be seen that all points from reader R1lies near to reference line rather than R2 and R3 with m_{R1} = 0.989 and R^2 = 0.9998. Figure 1(b) shows the points of $D_{meas}$from reader R2 lies under the reference line (also called as under response) with m_{R2} = 0.939 and R^2 = 0.9995 while Figure 1 (c), the points from reader R3 lies above the reference (over response) with m_{R3} = 1.035 and R^2 = 0.9994. If m_t value was compared with the values of *m*obtained from R1, R2 and R3, the differences in values show −0.011, −0.061 and 0.035 respectively. The percentage deviation of the gradient, Δ_m (%) for R1, R2 and R3 are −1.1%, −6.1% and 3.5% respectively.

R^2,as stated by Douglas *et al*. (2008), describes the strength of the linear relationship between two variables (in this case is the relationship between D_{meas} and D_{del} for each reader). R^2 that equal to zero (R^2=0) shows no correlation and R^2that equal to 1(R^2=1) indicate the perfect correlation between the variables. A weak correlation can be seen if the value lies between 0.00 and 0.50 while the strong correlation is shown when the value lies in the range of 0.50 to 1. The positive and negative sign only shows the direction of the linearity. If R^2 is closer to 1 (R^2≈1), the linear graph showed the best fit. Based on $R^2$from Figure 1, the straight lines for readers R1, R2 and R3 show good fit with strong positive correlation as their R^2 closer to 1 with difference in 0.0002 to 0.0005.

Table 1: The comparison of $D_{meas} \pm \Delta D_{meas}$and Δ (%) for readers R1, R2 and R3.

D_{del} (mSv)	$D_{meas} \pm \Delta D_{meas}$(mSv)			Percentage Deviation, Δ (%)		
	R1	R2	R3	R1	R2	R3
1.00	0.97 ± 0.03	0.99 ± 0.04	1.08 ± 0.04	−3.20	−0.90	7.90
3.00	3.01 ± 0.10	2.92 ± 0.08	3.05 ± 0.12	0.20	−2.70	1.63
5.00	4.86 ± 0.13	4.61 ± 0.09	5.05 ± 0.05	−2.76	−7.86	1.08
7.00	6.87 ± 0.18	6.62 ± 0.11	7.12 ± 0.08	−1.81	−5.50	1.69
10.00	9.91 ± 0.22	9.46 ± 0.11	10.41 ± 0.18	−0.93	−5.36	4.05

$\Delta\ (\%) = 100\ \text{x}[\frac{(D_{meas} - D_{del})}{D_{del}}]$

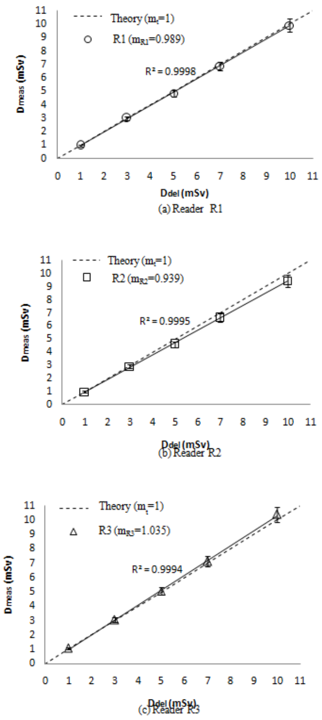

Fig. 1: D_{meas}versus$D_{del}$for the three readers using data pairs shown in Table 1. The gradients, *m* for theoretically and experimentally obtained straight- line were shown. Their deviationsΔ_m (%) were tabulated in Table 2.

Table 2: The experimental values of *m*, *c*, R^2 andΔ_m (%).

Reader	*m*	*c*	R^2	Δ_m (%)
R1	0.989	−0.021	0.9998	−1.1
R2	0.939	0.036	0.9995	−6.1
R3	1.035	−0.041	0.9994	3.5

$\Delta_m\ (\%) = 100\ \text{x}\ [\frac{(m-1)}{1}]$

Based on the Δ_m (%) calculated, it is seen that R1 is the suitable reader to be used as its Δ_m (%) is less than ± 1.5%. However, it cannot be simply concluded that the reader R2 and R3 are not suitable just based on the Δ_m (%). Thus, the evaluation on dose accuracy is done by using the trumpet graph recommended by the ICRP 1991. In this trumpet graph, all the values of *R*should lie in the limits of L_L and U_L. Based on the calculation for Formula in 4 and 5, R_{1mSv}, R_{3mSv}, R_{5mSv}, R_{7mSv}, and R_{10mSv},should be in the range of$0.55 \le R_{1mSv} \le 1.63$ for 1 mSv, $0.62 \le R_{3mSv} \le 1.55$ for 3 mSv, $0.64 \le R_{5mSv} \le 1.53$ for 5 mSv, $0.65 \le R_{7mSv} \le 1.52$ for 7 mSv, and $0.65 \le R_{10mSv} \le 1.51$ for 10 mSv.All the values of *R*in Table 3are then plotted in the trumpet graph as in Figure 2, to see whether the *R*is in the acceptance limit for doses 1, 3, 5, 7 and10 mSv assuggested by ICRP (1991). The results are satisfying as all the values of *R*of R1, R2 and R3 lied within thecalculated limits of L_L to U_L for each dose.

Table 3. The values of $R \pm \Delta R$ obtained for three readers.

D_{del} (mSv)	$R \pm \Delta R$		
	R1	R2	R3
1.00	0.97 ± 0.03	0.99 ± 0.04	1.08 ± 0.04
3.00	1.00 ± 0.03	0.97 ± 0.03	1.02 ± 0.04
5.00	0.97 ± 0.03	0.92 ± 0.02	1.01 ± 0.01
7.00	0.90 ± 0.03	0.95 ± 0.02	1.02 ± 0.01
10.00	0.99 ± 0.02	0.95 ± 0.01	1.04 ± 0.02

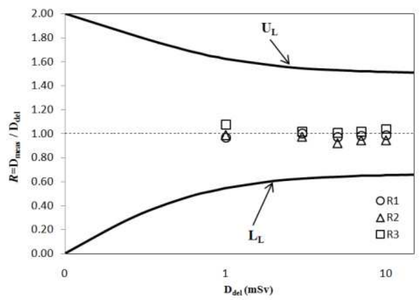

Fig. 2: Rfor readers R1, R2 and R3 in the trumpet graph, using data pairs shown in Table 3.

Conclusion:

Despite the two newly acquired readers which were R2 (Auto 200) and R3 (Auto 500) showeda slightly larger deviation compared to R1 (microStar reader) in the linearity test, they have been proven fit to be used for OSLD readings as they passed the accuracy test.

ACKNOWLEDGEMENT

This study is funded by Ministry of Higher Education Malaysia via the Fundamental Research Grants Scheme (FRGS/2/2013/SG02/UKM/01/3). Weare grateful to A.B.A.Kadirand W. Priharti for their assistance.

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