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

W.N.S.W. Ikmal, N.F. Muhamad and S.B. Samat

UniversitiKebangsaan Malaysia, School of Applied Physics, Faculty of Science and Technology, 43600 UKM Bangi, Selangor. Malaysia

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 = \( \frac{D_{\text{measured}}}{D_{\text{delivered}}} \) versus x = \( D_{\text{delivered}} \) was plotted for each reader. The experimental straight-line gradients \( m_{\text{R1}}, m_{\text{R2}} \) and \( m_{\text{R3}} \) (respectively for reader R1, R2 and R3) were compared with the theoretical gradient \( m_{\text{0.01}} \) which \( m_{\text{0.01}} = 1 \) and \( c = 0 \) in the equation of \( y = m_{\text{0.01}}x + c \). (b) For the accuracy test using the trumpet graph as suggested by the ICRP 1991, the experimental value for the five doses was compared with the theoretical values i.e. \( R_{\text{R1}}, R_{\text{R2}}, R_{\text{R3}}, R_{\text{R0.01}} \) and \( R_{\text{R0.01}} \) should respectively lie in the range of \( 0.95 \leq R_{\text{Ri}} \leq 1.05 \), \( 0.65 \leq R_{\text{R0.01}} \leq 1.5 \), and \( 0.65 \leq R_{\text{R0.01}} \leq 1.5 \). The ratio of the \( R_{\text{R0.01}} \) to \( D_{\text{delivered}} \). Results: For the first test, \( m_{\text{R1}}, m_{\text{R2}} \) and \( m_{\text{R3}} \) were found to be 0.989, 0.939 and 1.035. In percentage deviation of the gradient \( \Delta_{\text{R}}(\%) \) (compared to the theoretical) 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 \( \Delta_{\text{R}}(\%) \) less than \( \pm 1.5\% \). However, when the second test was 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.

INTRODUCTION

Secondary Standard Dosimetry Laboratory (SSDL) at Malaysia Nuclear Agency had been responsible in quality assurance of dosimeters. OSL 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 means the ability of the detector to give the same value of absorbed dose as the given dose. An ideal detector should have a signal that is linearly proportional to the absorbed dose of radiation for a given radiation field (Yukiaraand 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 (Yukiara and McKeever, 2011). Somehow in personal dosimetry, especially for dose range from 0.0001 to 10 Gy, they also stated that it had been reported for the OSL response of \( \text{Al}_2\text{O}_3\cdot\text{C} \) 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 \( ^{137}\text{Cs} \) and X-ray source of N120. They found that LiF detectors show a linear behaviour and performed well.

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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 32.7 cm x 23.2 cm x 10.9 cm in size. The other two were Auto 200 reader with dimension 110 cm x 46 cm x 38 cm and Auto 500 reader with dimension 110 cm x 49 cm x 77 cm. All readers yielded the readings of measured dose, D_{meas} for deep dose, H_{p}(10) and skin dose, H_{p}(0.07). However, only the readings of H_{p}(10) were used in this study. In this study, the readers of microStar, 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 control OSLD. Each controlled OSLD represented doses used for present study. Before the experiment day, all the OSLDs were annealed for fifteen seconds. When the experiment day had to be calculated it depends on the D_{del}.

Radionuclide source of gamma Co was exposed to specific doses. It was done to calculate the air kerma, K_{a} before the experiment day, t_{1/2(γ)} was half-life of gamma source and Δ 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}.

\[ t = \frac{\Delta x \times 60}{K_{a} x H_{p}(10)_{cc}} \]

Radionuclide source of gamma 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 amount of irradiation for specific doses. The air kerma, K_{a} on the experiment day had to be calculated first.

\[ K_{a} = K_{a\text{(ref)}} \times e^{-\frac{\text{ln}2 x 0.07}{t_{1/2(γ)}}} \]

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

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 20.20%. For reader R2, the values Δ % of the D_{meas} is within the range −5.36 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 shows the linear graph plotted on D_{meas} versus D_{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_{y} is equal to 1.

For Figure 1(a), it can be seen that all points from reader R1 lies near to reference line rather than R2 and R3 with m_{y1} = 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, $\Delta m$ (%) 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 $D_{\text{meas}}$ and $D_{\text{del}}$ for each reader). $R^2$ that equal to zero ($R^2 = 0$) shows no correlation and $R^2$ that 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 ($R^2 \approx 1$), 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 $D_{\text{del}}$, $D_{\text{meas}}$, and $\Delta (%)$ for readers R1, R2 and R3.

<table>
<thead>
<tr>
<th>Reader</th>
<th>$D_{\text{del}}$ (mSv)</th>
<th>$D_{\text{meas}}$ ± $\Delta D_{\text{meas}}$ (mSv)</th>
<th>Percentage Deviation, $\Delta (%)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>1.00</td>
<td>0.97 ± 0.03</td>
<td>$-3.20$</td>
</tr>
<tr>
<td>R2</td>
<td>3.00</td>
<td>3.01 ± 0.10</td>
<td>$0.20$</td>
</tr>
<tr>
<td>R3</td>
<td>5.00</td>
<td>4.86 ± 0.13</td>
<td>$-2.76$</td>
</tr>
<tr>
<td></td>
<td>7.00</td>
<td>6.87 ± 0.18</td>
<td>$-1.81$</td>
</tr>
<tr>
<td></td>
<td>10.00</td>
<td>9.91 ± 0.22</td>
<td>$-0.93$</td>
</tr>
</tbody>
</table>

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

### Table 2: The experimental values of $m$, $c$, $R^2$ and $\Delta m$ (%).

<table>
<thead>
<tr>
<th>Reader</th>
<th>$m$</th>
<th>$c$</th>
<th>$R^2$</th>
<th>$\Delta m$ (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>0.989</td>
<td>-0.021</td>
<td>0.9998</td>
<td>$-1.1$</td>
</tr>
<tr>
<td>R2</td>
<td>0.939</td>
<td>0.036</td>
<td>0.9995</td>
<td>$-6.1$</td>
</tr>
<tr>
<td>R3</td>
<td>1.035</td>
<td>-0.041</td>
<td>0.9994</td>
<td>3.5</td>
</tr>
</tbody>
</table>

$\Delta m (%) = 100 \times [\frac{m - m_t}{m_t}]$

Based on the $\Delta m$ (%) calculated, it is seen that R1 is the suitable reader to be used as its $\Delta m$ (%) is less than $\pm 1.5\%$. However, it cannot be simply concluded that the reader R2 and R3 are not suitable.
just based on the $\Delta m$ (%) 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, $R_{1mSv}, R_{3mSv}, R_{5mSv}, R_{7mSv}, \text{and} R_{10mSv}$ should be in the range of $0.55 \leq R_{1mSv} \leq 1.63 \text{for} 1 \text{mSv,} 0.62 \leq R_{3mSv} \leq 1.55 \text{for} 3 \text{mSv,} 0.64 \leq R_{5mSv} \leq 1.53 \text{for} 5 \text{mSv,} 0.65 \leq R_{7mSv} \leq 1.52 \text{for} 7 \text{mSv,} \text{and} 0.65 \leq R_{10mSv} \leq 1.51 \text{for} 10 \text{mSv}. \text{All the values of} R_{1}, R_{2} \text{and} R_{3} \text{laid within the calculated limits of} L_L \text{to} U_L \text{for each dose.}

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

<table>
<thead>
<tr>
<th>$D_{del}$ (mSv)</th>
<th>$R \pm \Delta R$</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>R2</td>
</tr>
<tr>
<td>1.00</td>
<td>0.97 ± 0.03</td>
</tr>
<tr>
<td>3.00</td>
<td>1.00 ± 0.03</td>
</tr>
<tr>
<td>5.00</td>
<td>0.97 ± 0.03</td>
</tr>
<tr>
<td>7.00</td>
<td>0.90 ± 0.03</td>
</tr>
<tr>
<td>10.00</td>
<td>0.99 ± 0.02</td>
</tr>
</tbody>
</table>

Fig. 2: $R$ for 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) showed a 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.

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REFERENCES


Reuven, C., 2001. Advantages and Disadvantages in the Utilisation of thermoluminescence (TL) and Optically Stimulated Luminescence (OSL) for Radiation Dosimetry. IRPA Regional Congress on Radiation Protection in Central Europe Dubrovnik, Croatia.