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Dose Response of Personnel OSL Dosimeter to the Cesium-137 and 80 kVp X-ray Exposure

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ABSTRACT

Over the years, several types of dosimeters have been introduced for accurate dose assessment. The OSL dosimeter is one of them. It is used to monitor personnel dose from external exposure. In this paper, dose response of OSL dosimeters in terms of $H_p(10)$ to Cs-137 gamma and 80 kVp X-ray radiation will be studied. The dosimeters were irradiated using Cs-137 gamma and 80 kVp X-ray to 0.5 mSv, 1 mSv, 3 mSv, 5 mSv, and 10 mSv at a distance of 200 cm, and all of them were subsequently read. Half of the dosimeters that were previously irradiated with a dose of 1 mSv and 5 mSv were read 30 times. The other half of the dosimeters were re-read on day 30 and day 60 from the initial reading. The study shows that relations between measured dose and exposure dose for Cs-137 gamma and 80 kVp X-ray irradiation are linear with correlation coefficients (R^2) of 0.9997 and 0.9987, respectively. When the OSL dosimeters were read repeatedly, a dose reduction for each reading occured by 0.4 % and 0.5 % on Cs-137 gamma and 80 kVp X-ray, respectively. Dose reading on day 60 after Cs-137 gamma irradiation showed fading of 3.6 % and 2.7 % on OSL dosimeter exposed to 1 mSv and 5 mSv, respectively, whereas fading effect on 80 kVp X-ray irradiation showed values of 5.9 % and 8.8 % for the two doses.

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INTRODUCTION

Currently, gamma and X-ray are widely used in the industrial and medical fields. To ensure that the use of the radiation sources is safe for radiation workers, the licensee is required to monitor the dose received by radiation workers [1]. Over the years, several types of dosimeters have been introduced for accurate dose assessment [2]. Thermoluminescent dosimeters (TLDs or TL dosimeters) are widely used in personnel dose monitoring. However, high-temperature heating is required to release electrons trapped in the holes in the valence band [3]. The process of reading the dose requires nitrogen gas. Compared to the TLD, the optically-stimulated luminescent dosimeter (OSLD or OSL dosimeter), which is made of Al_2O_3:C, has several advantages. High sensitivity, good precision for low dose measurement, possible re-analysis, high readout speed, elimination of thermal annealing step, and low fading are the advantages of OSL dosimeters [4,5]. Hashim et al. [5] tested the response of $H_p(10)$ to OSL dosimeter in Co-60 irradiation teletherapy to obtain linearity and signal depletion characteristics on repeated dose readings. Jumpeno, Ardyanti, and Afham [6] showed that no fading occurred on the re-reading at the 31st day after Cs-137 gamma irradiation. Kadir et al. [7] reported that the OSL dosimeter showed a better response to photon of various energies compared to the TLD-100 and the TLD-100H.

As stipulated by the Regulation of the Head of Nuclear Energy Regulatory Agency No. 4 Year 2013, the TL dosimeter is one of the dosimeters that can be used to monitor personnel dose from external radiation exposure [1]. The TL dosimeter is equivalent to the OSL dosimeter. However, their operation differ in that in the OSLD, the crystal lattice relies on optical stimulation to emit

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luminescence light, while TLD is stimulated by heat. Jumpeno, Rahayu, and Ardyanti [8] tested the OSL dosimeter and the TL dosimeter under Cs-137 gamma irradiation and 80 kVp X-ray irradiation to determine the differences in $H_p(10)$ dose response. Connor [9] stated that $H_p(10)$ is the dose equivalent in ICRU tissue at a depth of 10 mm in a human body below the position where an individual dosimeter is worn.

In this work, the personnel OSL dosimeter response in terms of $H_p(10)$ will be studied, in addition to the linearity of the relation between measured dose and exposure dose, signal depletion on repeated dose reading, and the effect of fading.

METHODOLOGY

Materials and instruments

Optically-stimulated luminescence (OSL) is the luminescence from irradiated semiconductor (Al_2O_3:C) when exposed to light. The personnel OSLD is designed for personnel radiation exposure monitoring. The Landauer OSLD is also made of Al_2O_3:C. The detector element is sandwiched between two layers of polyester, each 0.3 mm thick. The dosimeter element (casing) is inserted into the dosimeter badge whose dimension is 6.3 cm × 3.8 cm × 0.9 cm. The casing is 5 cm × 2.4 cm × 0.6 cm in size. The commercial type of OSLD for personnel $H_p(10)$ dose monitoring here has the code of XA. Figure 1 shows the OSLD casing and dosimeter badge for personnel dose monitoring. The dose of $H_p(10)$ on the OSL dosimeter is read using a microSTAR OSLD reader equipped with the InLight microSTAR reader software package version 2.0.12.23229.

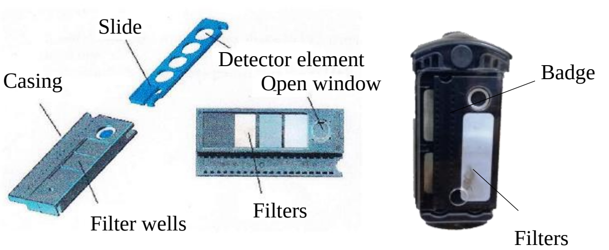

Fig. 1. OSL dosimeter casing with radiation filters (left) and dosimeter badge (right) [8].

Irradiation with gamma from Cs-137 dose irradiation was carried out at the OB-85 Gamma Calibration Facility, LTRSM-NRIA (Laboratory for Technology of Radiation Safety and Metrology - National Research and Innovation Agency), Pasar Jumat, Jakarta, Indonesia as shown in Fig. 2. (a). The Cs-137 source had an activity of 740 GBq in March 1985. Meanwhile, X-ray irradiation was carried out using the Philips YXLON MG320 X-ray generator at the Calibration Facility of the Secondary Standard Dosimetry Laboratory (SSDL), Mampang, Jakarta, Indonesia as shown in Fig. 2. (b).

(a)

(b)

Fig. 2. Irradiation devices at LTRSM-NRIA used here (a) OB 85 calibration facility; and (b) Philips YXLON MG320 X-ray calibration facility.

Procedure

Forty-eight OSL dosimeters were annealed and read to ensure that the dose information was reset to zero. Then, they were attached to the dosimeter badge. All dosimeters and their badges were labeled with markers. The dosimeters were divided into two groups, namely, 24 dosimeters for irradiation with Cs-137 gamma emission, and the rest with 80 kVp X-ray. Each of the two groups was divided into six smaller groups consisting of four dosimeters each. The first five smaller groups were irradiated at 0.5 mSv, 1 mSv, 3 mSv, 5 mSv, and 10 mSv, respectively, while the sixth smaller group served as control dosimeters. Irradiation with Cs-137 was carried out at the Gamma Calibration Facility, LTRSM-NRIA, at a distance of 200 cm. The irradiation was done using a phantom slab of 30 cm × 30 cm × 15 cm size. Meanwhile, the irradiation using 80 kVp X-ray was carried out at the Calibration Facility of Secondary Standard Dosimetry Laboratory. It was carried out from a 200 cm distance. This irradiation was carried out using a 30 cm × 30 cm × 12 cm phantom. Following a delay of one night after exposure, all dosimeters were read, three times each, using the microSTAR

OSL reader. The dosimeters, $H_p(10)$ dose response and the linearity of the relationship between measurement dose and exposure dose were analyzed.

Each of the two dosimeters that were previously irradiated with a dose of 1 mSv and 5 mSv were read 30 times each. The decrease of the $H_p(10)$ dose reading on the OSL dosimeter caused by repeated readings was analyzed. To determine the fading effect due to the reading interval, another four OSL dosimeters exposed to doses of 1 mSv and 5 mSv were re-read on day 30 and day 60 from the initial reading.

RESULTS AND DISCUSSION

Dose response and linearity

The dose response of $H_p(10)$ to Cs-137 gamma and 80 kVp X-ray irradiations to the OSL dosimeter is shown in Table 1.

Table 1. $H_p(10)$ dose response of OSL dosimeters for Cs-137 gamma and 80 kVp X-ray irradiation.

Exposure Dose (mSv)	Cs-137 Gamma			80 kVp X-ray		
	Measured Dose (mSv)	Uncertainty (%)	Ratio Measured Dose to Exposure Dose	Measured Dose (mSv)	Uncertainty (%)	Ratio Measured Dose to Exposure Dose
0.5	0.32	24.2	0.64	0.48	12.3	0.96
1	0.80	14.1	0.80	1.05	10.7	1.05
3	2.79	8.7	0.93	3.58	13.0	1.19
5	4.68	7.8	0.94	5.53	6.9	1.11
10	9.29	7.9	0.93	10.90	5.7	1.09

The deviation of measured dose ($D_{Measured}$) from exposure dose ($D_{Exposure}$) is relatively large at 0.5 mSv exposure dose and smaller at higher exposure doses.

The trend is similar to the dose irradiation of Cs-137 performed at intercomparison of $H_p(10)$ for OSL dosimeter [10] and Kobayashi et al. research [11]. However, a different trend was observed for 80 kVp X-ray irradiation. On the exposure dose of 3 mSv, the deviation of the measured dose to the exposure dose is relatively higher. The difference in the deviation is likely due to voltage instability in the X-ray generator when operating for irradiation.

Figure 3 shows that the relation between measured dose and exposure dose for both Cs-137 gamma and 80 kVp X-ray irradiation are linear with correlation coefficient (R^2) values of 0.9997 and 0.9987, respectively. The measured dose for gamma irradiation tends to be underestimated with a linear equation of $y = 0.9442x - 0.1065$, while for X-ray irradiation, the dose response tends to be overestimated with a linear equation of $y = 1.0925x + 0.0474$. Previous research conducted by Jain et al. [12], Hashim et al. [5], Jumpeno, Ardyanti, and Afham [6], Monthonwattana et al. [13], and Karim et al. [14] also showed linear relationships between measured dose and exposure dose on OSL dosimeters for gamma and X-ray irradiation with correlation coefficients of ≥ 0.997.

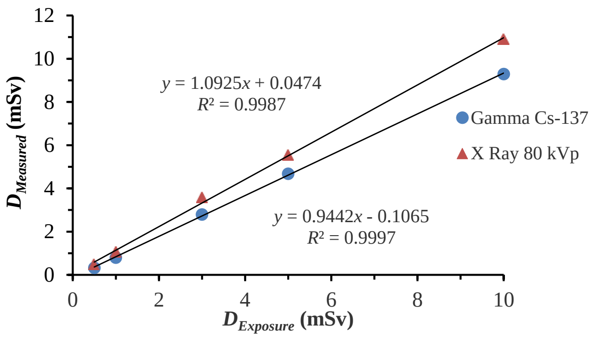

Fig. 3. Correlation curve between measured dose and exposure dose on Cs-137 gamma and 80 kVp X-ray irradiation to OSL dosimeter.

Dose depletion

The percentage of OSL dose after depletion after 30 reading repetitions of OSL dosimeter for Cs-137 gamma and 80 kVp X-ray irradiations at 1 mSv and 5 mSv is displayed in Fig. 4.

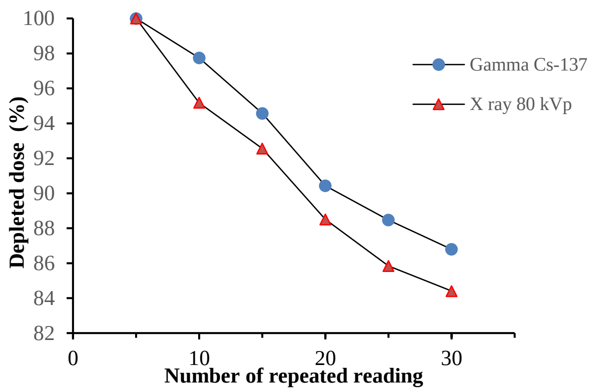

Fig. 4. OSL depleted dose for 30 readings obtained by averaging the dose every 5 readings.

After the dosimeters were read 30 times, there was a decrease in dose reading of 13 % for Cs-137 gamma and 17 % for 80 kVp X-ray. Therefore, every time the OSL dosimeter is read, there is a dose reduction of 0.4 % for gamma ray and 0.5 % for X-ray. Hashim et al. [5] reported a reduction of dose following gamma irradiation using Co-60. Meanwhile, Musa et al. [15] reported a dose reduction of 0.57 % per reading of a nanoDot OSL after a 20 mGy irradiation of using 80 kV X-ray.

Jursinic [16] stated that for each reading, the OSL signal decreases by 0.05 % following an 6 MV X-ray irradiation on a nanoDot OSL dosimeter. It can be seen that the dose reduction for each reading on the OSL dosimeter ranges from 0.4 % - 0.57 % per reading, except for the study conducted by Jursinic. This characteristic is one of the advantages of OSLD compared to TLD. Meanwhile, Landauer based on Ford, Hanify, and Perks [17] reported a depleted dose value on OSLD of less than 0.4 % per reading.

Fading

The fading effect of the OSL dosimeter following Cs-137 gamma and 80 kVp X-ray irradiations is shown in Fig. 5. Dose reading on day 60 after Cs-137 gamma irradiation showed fading of 3.6 % and 2.7 % on OSL dosimeter exposed to 1 mSv and 5 mSv respectively. Meanwhile, after 80 kVp X-ray irradiation, fading occurs by 5.9 % and 8.8 % for the two exposure doses and day of reading after irradiation which are the same. Jensen et al. [18] in their research found no significant fading of the OSL signal over 85 days at room temperature for Co-60 irradiation. Jumpeno, Ardyanti, and Afham [6] reported OSL fading of 2.4 % and 3.4 % for 5 mSv and 10 mSv Cs-137 gamma exposure when read on the 70th day after irradiation. Meanwhile, Scarboro et al. [19] stated that there was no significant trend seen for fading after 240 hours of irradiation of 120 kV CT beam to nanoDot OSLDs. The fading of OSL dosimeters varies with respect to irradiation. The energy of photon received and the OSL dosimeter use cycle are likely to cause differences in the fading effect on OSL dosimeters.

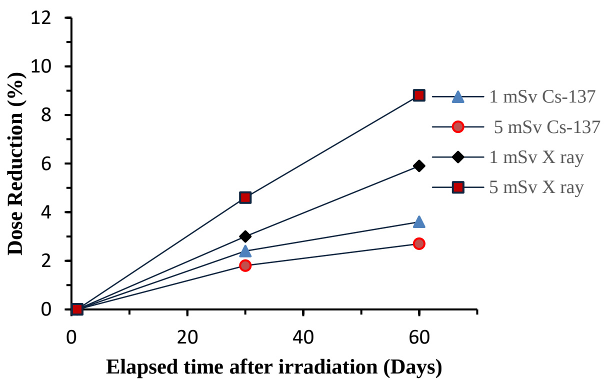

Fig. 5. Fading effect of OSL dosimeter after gamma ray and X-ray irradiation.

CONCLUSION

The study of dose response of the personnel OSL dosimeter to Cs-137 gamma ray and 80 kVp X-ray uncovered linear behaviors with correlation coefficients of 0.9997 and 0.9987, respectively. The re-reading of the OSL dosimeter after irradiation with Cs-137 gamma and 80 kVp X-ray showed a dose reduction of ≤ 0.5 % per reading. Repeated readings will not affect the dose response of the OSL dosimeter significantly. The fading effect of OSL dosimeter after 60 days has elapsed after irradiation was ≤ 3.6 % for Cs-137 gamma and ≤ 8.8 % for 80 kVp X-ray.

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AUTHOR CONTRIBUTION

The first author, E. B. Jumpeno, is the main contributor to this paper. All authors read and approved the final version of the paper.

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