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Preparation for Eye Lens Dose Assessment at CSTRM-NNEA

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Abstract

Because of the negative impact of radiation on the eye lens and the changes recommended by the International Commission on Radiological Protection (ICRP) 103 (2007) from 150 to 20 mSv (2 rem, the Regulation of BAPETEN Head No. 4 (2013) article 56 give the instruction that Monitoring of eye lens dose should be implemented starting from March 13, 2016, more intensive around the eye lens. To prepare eye lens dose assessment, The Center for Safety Technology and Radiation Metrology (CSTRM) - NNEA study the response of TLD-700H against the X-ray: N (80), N (100) and N (120) energies (usually used in the interventional radiology). Goals and objectives of this study were to obtain the response/calibrated TLD-700H which is traceable to the international system (SI) and TLD-700H can be used for an eye lens dose assessment in Indonesia. Twenty-one TLDs were irradiated with seven dosage variations (0.1; 0.5; 1; 5; 10; 15; 20) mSv at the Secondary Standard Dosimetry Laboratory (SSDL) - Jakarta. After being stored for 24 hours, the TLD were read by using TLD-Reader. The Dosimeter Response, R against doses of X-ray were: R(N80) = 34.595x + 0.1262; $R^2 = 0.9986$; R(N100) = 24.484x + 1.1357; $R^2 = 0.9993$; and R(N120) = 27.908x - 5.1065; $R^2 = 0.9971$. R: correlation coefficient, x: doses; These calibration responses can be used for eye lens dose assessment in Indonesia.

Keywords: Eye Lens Dose; Hp (3); TLD-700H.

1. Introduction

The use of ionizing radiation in medical institutions is increasing year by year, but the negative impact of radiation on the eye lens is increased, especially in the interventional radiology, reported by Chodick et al. (2008) and Vano et al. (2010) [1, 2]**.** Research to estimate eye lens dose in interventional radiology have been done by Principi et al. (2015) [3], and other similar **r**esearch**,** "Eye dosimetry and protective eye wear for interventional clinicians" was carried out by Martin et al. (2015) [4]**.** Research "Assessment of eye lens doses for workers during interventional radiology procedures" was done by Urboniene et al. (2015) [5], and research **"**Risk of radiation exposure to medical staff involved in interventional endourology**"**, reported by Hristova-Popova et al. (2015) [6]. Research **"**Eye lens monitoring for interventional radiology personnel**"** was carried out by Carinou et al. (2015) [7].

Research "Occupational Dose Assessment in Interventional Radiology in Serbia", was done by Kaljevic et al. (2015) [8] and research "The Current Status of Eye Lens Dose Measurement in Interventional Radiology Personnel in Thailand" was carried out by Krisanachinda et al. (2017) [9]. Research "Eye Lens Dosimetry and The Study on Radiation Cataract in Interventional Cardiologists", reported by Matsubara et al. (2017) [10]. Research "The Exposure of The Eye Lens Personnel in Nuclear Medicine Department", Research "Personnel in the Facilities that Produce Radiopharmaceuticals for The Purpose of Diagnosis by Positron Emission Tomography" and Research "Is Eye Lens Dosimetry Needed in Nuclear Medicine?" as well as Research "In the Procedure of Dispensing the Doses of ^{68}Ga-DOTA-TATE for Patients", carried out by Wrzesień et al. (2018) [11, 12]. Research "Should Personnel of Nuclear

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Medicine Departments Use Personal Dosimeters for Eye Lens Dose Monitoring?" was written by Piwowarska-Bilska et al. (2019) [13].

Lens of the Eye Dosimetry has become increasingly important with the changes recommended by The International Commission on Radiological Protection (ICRP)-103 (2007) [14], Statement on Tissue Reaction. The ICRP issued new recommended limits for radiation dose to the lens of the eye, Hp (3) due to concerns over cateracts in April 2011 [15]. This reduction annual dose limits to the lens of the eye from 150 to 20 mSv (2 rem) has created the need for enhanced monitoring using dosimeter as close as possible to the eye.

In Indonesia, based on the Government Regulation of the Republic of Indonesia No.63 (2000) [16], concerning Safety & Health of Ionizing Radiation, "In every utilization of ionizing radiation, the safety factor of the workers must be given on the highest priority". Acceptance of radiation doses by radiation workers must kept as low as possible so as not to exceed the dose limit value permitted by the Supervisory Board. According to the Government Regulation of the Republic of Indonesia No. 33 (2007) [17], concerning Safety of Ionizing Radiation and Radioactive Source Security, "Safety measures are needed to protect workers, community members and the environment from radiation hazards".

Based on the Reglation of BAPETEN Head No. 4 (2013) [18], article 56 (paragraph 1), "Monitoring of eye lens dose should be implemented starting from March 13, 2016, especially for radiation workers who work in special places that requires monitoring dose more intensive around the eye lens.

Goals and objectives of this study are as Preparation for Eye Lens Dose Assessment of the Interventional Radiology Personnel in Indonesia using Thermoluminescent Dosimeter-700H. Based on the Regulation of NNEA Head No. 21 (2014) [19], the CSTRM of NNEA has the responsibility to study the response of dosimeter, initially on the energy of X-ray: N(80), N(100) and N(120), which were used in the interventional radiology. This study is to obtain the calibrated TLD-700H which was traceable to the international system (SI) through the national reference, so TLD-700H can be used for eye lens dose assessment the interventional radiology personnel in Indonesia

2. Research Methodology

According to IAEA-Safety Standards Series, Safety Guide No. RS-G-1.3 (1999) [20], TLD-700H was LiF: Mg, Cu, P (Figure 1). It has Z_{eff}: 8.3, and main peak: 210^{o}C, maximum emission is 400 nm, and relative sensitivity: 25% and fading at 25^{o}C: can be ignored. This dosimeter can monitor beta radiation, gamma and X-rays. The chip for TLD-700H is XD-707H, it has a density of 7 mg/cm^2,

Before used to monitor eye lens dose, the uniformity or homogeneity response of 30 new TLDs-700H were studied. Every three dosimeters were attached on the surface of cylindrical phantom (Figure 2) and then irradiated by ^{90}Sr with 0,334 mSv. After being stored for 24 hours, the dosimeters were read by using TLD-Reader type 6600 (Figure 4). The dosimeter uniformity was presented in Figures 5a and 5b. By using the same way, the stability testing of dosimeters was done by irradiating the dosimeters against ^{90}Sr, in different time. After being stored for 24 hours, the dosimeters were read, and the stability test was presented in Figure 6.

The dosimeter was tested for the angle of incidence of radiation. The dosimeter was placed on the surface of cylinder phantom, at the angle of 0^o; ±20^o; ±40^o; and ±60^o from X-ray, N (80), (Figure 3), with a dose of 10 mSv. After being stored for 24 hours, the dosimeters were read. The results were presented in Figure 7.

The X-ray/YXLON-MG325 (Figure 3) was set on 20 mA and FOC: 5.5. For N (80), it was used added filter 2.028 mmCu, for N (100), it was used added filter 5.152 mmCu and for N (120), it was used added filter 5 mmCu and 1 mm Sn. For the measurement of air Kerma rate, it was used Ionization Chamber 600 cc NE2575C/#576, connected by electrometer PTW Unidose. Dose rate was 4.367 nC/minutes, Calibration Factor, N_K for N (80) was 43.25 µGy/nC, N_K for N (100) was 42.64 µGy/nC, and N_K for N (120) was 42.53 µGy/nC, in the year of 2015. Ionization Chamber 600 cc NE2575C/#576 was traceable to IAEA.

According to IAEA-SRS No.16 (2000) [21], the new TLD-700H should be calibrated. The TLD were inserted in the available chipstrate bag on the headband and attached on the surface of cylindrical phantom (Figure 2), at source detector distance (SDD) of 200 cm from the X-ray. The TLD were irradiated by using N (80), N (100) and N (120) at the Secondary Standard Dosimetry Laboratory (SSDL), in South of Jakarta, with 7 dosage variations (0.1; 0.5; 1; 5; 10; 15; 20) mSv. It was used 3 dosimeters for irradiate one dose. After being stored for 24 hours, the TLD were read by using TLD-Reader. The data were plotted: the response of TLD-700H against doses were presented in Figure 8a, 8b and 8c, and the response of dosimeter against energy were plotted in Figure 9. Now, TLD-700H is ready to be used as eye lens dosimeter.

According to BIPM, ISO/IEC GUIDE 98-3 (2008) [22], the overall uncertainty of a dosimetric system was determined from the combined uncertainty (Type A and Type B). The standard uncertainty of Type A, u_A was identified with standard deviation, s ($\bar{X}$) of a series of measurements. Typical sources of Type A uncertainty were from: uniformity, stability, variability of detector reading at zero dose, and detector reading at the dose. Type B uncertainties, u_B were from: calibration error, energy dependence, directional dependence, fading, and effect due to exposure to light.

The combined uncertainty is:

$$u_c = \sqrt{u_A^2 + u_B^2} \tag{1}$$

The Expanded uncertainty is:

$$u_{exp} = k \times u_c \tag{2}$$

Where k is coverage factor, k = 2, for 95% Confidence Level.

Figure 1. TLD-700H

Figure 2. TLD-700H with headband on the surface of Cylindrical phantom

Figure 3. YXLON-MG325 X-Ray

Figure 4. TLD-Reader

3. Results and Discussion

To know the uniformity or homogeneity of the new TLD, the TLD were irradiated by using beta source, ^{90}Sr or other long half -life radionuclide (in this study it was used ^{90}Sr with a dose: 0.334 mSv). The result of uniformity test was quite uniform, with a standard deviation of the average was 1.6% and 1.7%, at 67% confidence level (see Figures 5a and 5b). The uniformity was obtained between Lower Warning Level (LWL) and Upper Warning Level (UWL). The standard deviation of uniformity will contribute to dose evaluation.

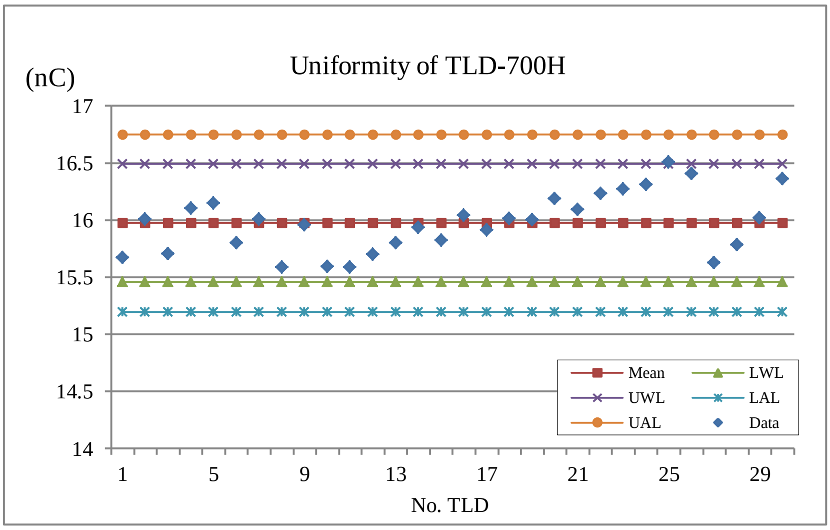

Figure 5a. Uniformity of TLD-700 against ^{90}Sr (1)

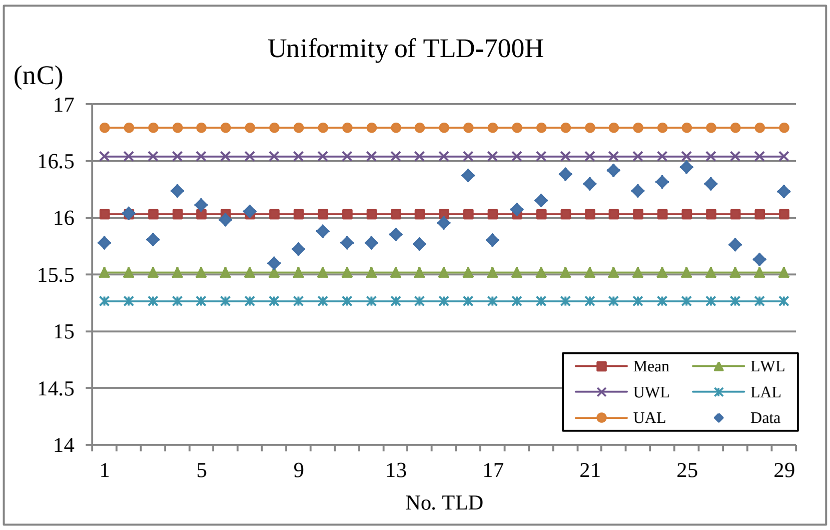

Figure 5b. Uniformity of TLD-700 against ^{90}Sr (2)

Stability test of dosimeters were done by irradiating the dosimeters against ^{90}Sr, at different time. After being stored for 24 hours, the dosimeters were read, and the stability test result was presented in Figure 6a and 6b, and the stability of TLD-700H was 2 % (at the CL: 67%).

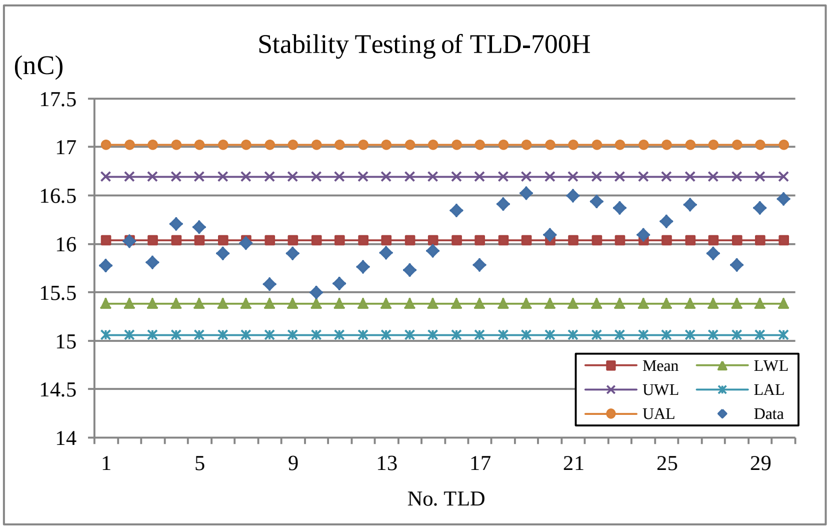

Figure 6a. Stability testing of TLD-700H by using ^{90}Sr (1)

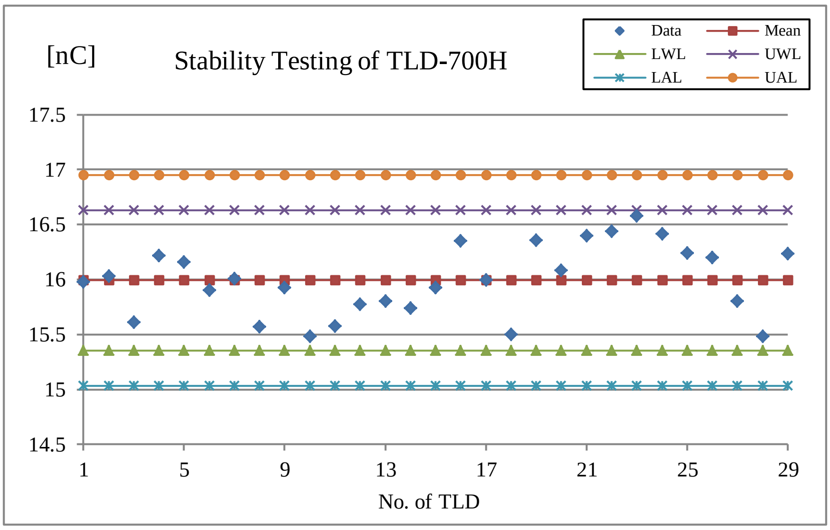

Figure 6b. Stability testing of TLD-700H by using ^{90}Sr (2)

The TLD's Response against the angles of X-ray incidence, R (Θ) was studied. Every three dosimeters were placed on the surface of cylindrical phantom, at the angle of 0°; ±20°; ±40°; and ±60° from X-ray N (80) (Figure 3) with a dose of 10 mSv. After being stored for 24 hours, the dosimeters were read. The results were presented in Figure 7.

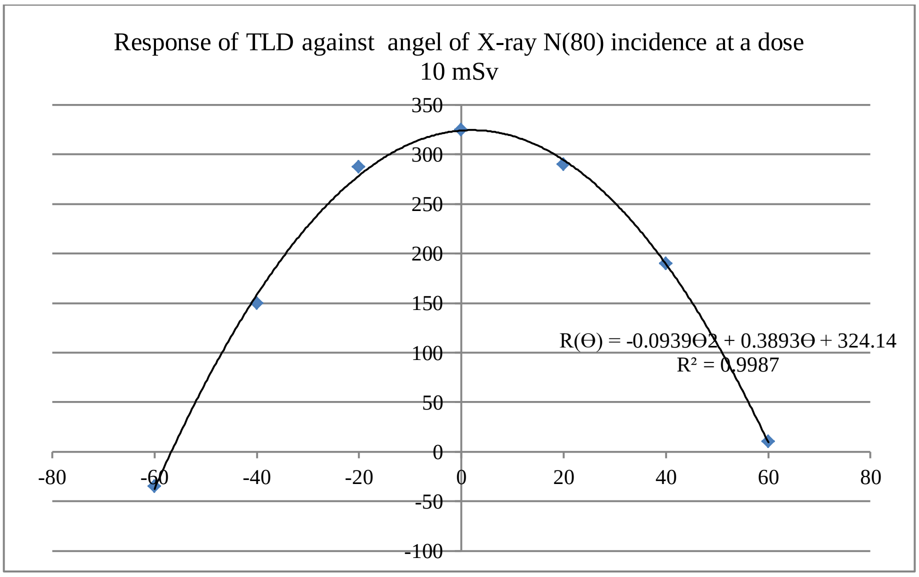

Figure 7. Response of TLD against x-ray N (80) incidence

The Response of TLD-700H against X-Ray doses was presented in Figure 8. It can be seen that the TLD response to the dose was linear, the larger the dose, the greater the response. In Figure 8 there were three responses for three energy. If TLD-700H was worn on the head of radiation worker at IR, it can collected/absorbed the dose. Every three months, the TLD should be submitted to the CTRSM to be evaluated. Unfortunately, TLDs-700H have not been used as an eye lens dosemeter, they still use TLD for personal dosimeter, Hp (10), so we do not know the eye lens dose accepted by the interventional radiology personnel.

According to Krisanachinda et al. (2017) [9], Nano Dots of the optically stimulated luminescence (OSL) dosimeter has been used as an eye lens dosimeter for 16 interventional radiology personnel, in Thailand, both with and without lead-glass eyewear. The mean effective dose at the body, equivalent dose at the collar, and estimated eye lens dose were 0.801, 5.88, and 5.70 mSv per year, respectively. The mean eye lens dose measured by the Nano Dots dosimeter was 8.059 mSv per year on the left eye and 3.552 mSv per year on the right eye. Two of 16 interventional cardiologists received annual eye lens doses on the left side without lead glass that were higher than 20 mSv per year, the new eye lens dose limit as recommended by ICRP with the risk of eye lens opacity and cataract.

The TLD response against X-Ray energies: N (80) to N (120) was presented in Figure 9. In Figure 9, it can be seen that the response of TLD at 80kV is higher than at 100 kV and then increase at 120kV. This is consistent with the photo electric effect. Besides that is to know the TLD response against energy between these energies (interpolation).

The Nuclear Energy Supervisory Agency in Indonesia (BAPETEN) should do inspections to the Interventional Radiology (IR) and Nuclear Medicine (NM) departments to explain about the dangers of radiation to the lens of the eye and the importance of monitoring the dose in the eyepiece using TLD-700H, because the dose limit on the eyepiece was reduced to 20 mSv per year.

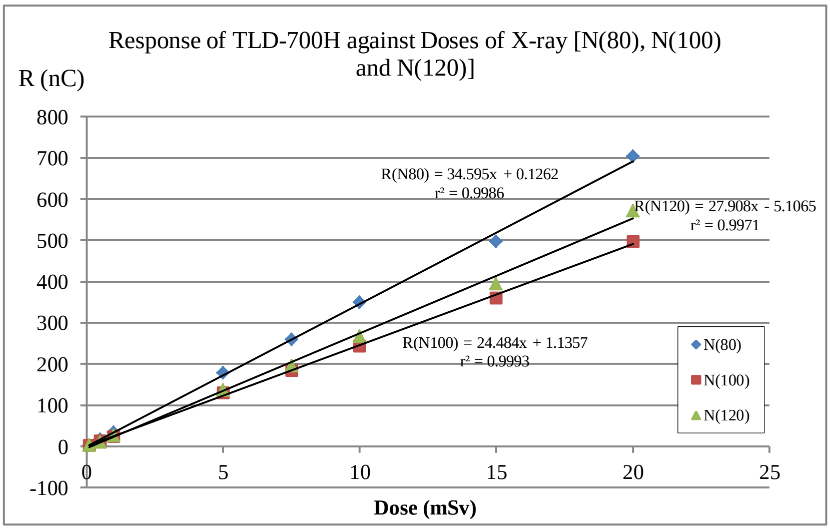

Figure 8. Response of TLD-700H against doses of X-ray [N (80), N (100) and N (120)]

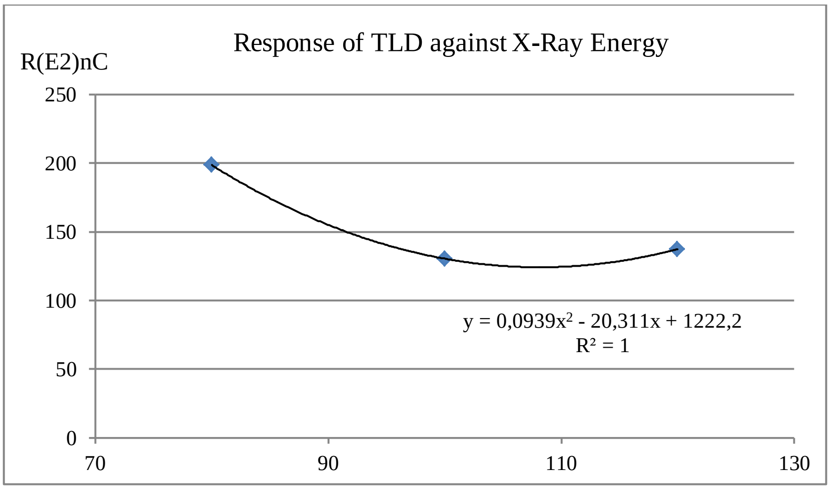

Figure 9. Response of TLD against energies of X-ray (at 5 mSv)

The expanded uncertainty, U_{exp} of Eye Lens Dose Assessment using TLD-700H was:

$$U_{exp} = 2 \times u_c = 2 \times \sqrt{u_A^2 + u_B^2} \quad (3)$$

Type A uncertainty → u_A: uniformity uncertainty, u_{unif} ; stability uncertainty, u_{stab}. Uncertainty of variability of detector reading at zero dose, $u_{BG,}$ and detector reading uncertainty at the dose, u_D

Type B uncertainty, u_B: calibration error, u_{cal}; energy dependence, u_E directional dependence, u_Θ; fading. u_F.

$$U_{exp} = 2 \times u_c = 2\times \sqrt{[(u_{unif})^2 + (u_{stab})^2 + (u_{BG})^2 + (u_D)^2 + (u_{cal})^2 + (u_E)^2 + (u_\theta)^2 + (u_F)^2]} \quad (4)$$

4. Conclusions

To prepare eye lens **d**ose **a**ssessment, the CSTRM has done the following procedure:

- The uniformity of a new TLD-700H was checked by irradiating the TLD against ^{90}Sr (or using another long half-life radionuclide). The TLD-700H was quite uniform, with standard deviation of the mean: (1.6% and 1.7%) for CL: 67%.

- The stability of the TLD was checked against ^{90}Sr. The result was 2 %, for the CL: 67%.
- The TLD response was checked against angle, R(Θ) to X-ray N (80). Θ: angle of coming radiation: 0^o, $\pm 20^o$; $\pm 40^o$; and $\pm 60^o$. The response was $R(\Theta) = -0.0939\Theta^2 + 0.3893\Theta + 324.14$, $R^2 = 0.9987$
- The TLD-700H response against doses of X-ray were:

  $R(N80) = 34.595x + 0.1262$; $R^2 = 0.9986$; x = doses

  $R(N100) = 24.484x + 1.1357$; $R^2 = 0.9993$; x = doses

  $R(N120) = 27.908x - 5.1065$; $R^2 = 0.9971$; x = doses
- The TLD-700H response to the energy of X-rays, R(E), within (80-120) kV was:

  $R(E) = 0.0939 E^2 - 20.311 E + 1222.2$; $R^2 = 1$.
- The tendency of TLD response was increased below 100 kV and above 100 kV. To prove this conclusion, this study should be continued by irradiated TLD-700H at energies below 80 kV and above 120 kV.
- The CSTRM-NNEA is ready to evaluate the eye lens dose of the Interventional Radiology (IR) personnels in Indonesia using TLD-700H.
- It was recommended that the eye lens dose, Hp (3) doses be routinely monitored in the group of the radiopharmacists who label pharmaceuticals with the radionuclide ^{99m}Tc and in chemists working in ^{18}F-FDG quality control departments in production units.
- The assessment of doses to the lens of the eye, Hp (3) in the IC in Indonesia has not been done yet in the period of 2013-2019.

5. Acknowledgements

The authors thanks to the Functional Technical Advisory Commission for reviewing this paper and to CSTRM-NNEA for the funding to this research

6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

7. Ethical Approval

All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

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