A Malaysian Secondary Standard Dosimetry Laboratory participation in the IAEA/WHO Postal Dose Quality Audit: Data Analysis 2009 – 2019

N Abdullah¹,a and M T Dolah¹
¹Radiation Metrology Group, Malaysian Nuclear Agency (Nuklear Malaysia), 43000 Kajang, Selangor, Malaysia

Abstract. Participation of Secondary Standard Dosimetry Laboratory (SSDL) of Malaysia in the IAEA/WHO Postal Dose Quality Audit Service is very important in confirming the traceability of absorbed dose measurements provided to the radiotherapy centres. In the audit, the SSDL was supplied with a set of dosimeter for irradiation with absorbed dose to water of 200 cGy in reference conditions using $^{60}$Co teletherapy or medical linear accelerator. In the period of 2009 to 2019, a total of 10 photon beams from $^{60}$Co teletherapy unit, 6 MV X-ray and 10 MV X-ray produced by medical linear accelerator have been audited. The results of the audit demonstrate that the mean of percentage deviations between the SSDL and the IAEA measurements was -0.35% with standard deviation of 0.86%. The deviations vary between a minimum percentage relative deviation of -2.5% and a maximum of 0.6%. These results were considered satisfactory in which complied with the IAEA’s acceptance limit of ± 3.5%.

1. Introduction
Radiation therapy is an important method to treat cancer with the aim to deliver as maximum doses as possible to the tumour while protecting the surrounding healthy tissue and organs at risk [1-2]. It is essential to confirm the accuracy of dose delivered to patient is within the tolerance limit of 5% at 95% confidence level [3-4]. Radiation underdose or overdose delivered clinically should be avoided in order to improve the effectiveness of the cancer treatment as well as to avoid radiation injuries to patient [5-11]. Therefore, a postal dosimetry audit often conducted as a part of Quality Assurance Programme (QAP) in radiotherapy where the dosimeters are mailed to the radiotherapy centres for irradiation to verify the accuracy of the dosimetry measurements [12-13]. In addition, the audit can be used as a tool for confirming the competency of medical physicist and ensuring the measurement traceability provided by national dosimetry laboratory [1][7-9].

The Secondary Standard Dosimetry Laboratory (SSDL) of Malaysian Nuclear Agency (Nuklear Malaysia) has been appointed by the National Metrology Institute of Malaysia (NMIM) as the designated institute for ionizing radiation measurement in Malaysia. The laboratory carries the responsibility for delivering precise, accurate and reliable dosimetry calibrating factors to the users in compliance to the Atomic Energy Licensing Act 1984 (ACT 304) as well as keeping abreast with the
development of SSDLs network worldwide. Besides being a member of the International Atomic
Energy Agency (IAEA) / World Health Organization (WHO) Network of SSDLs since 1979, the
SSDL of Nuklear Malaysia is also a member of the Asia Pacific Metrology Programme (APMP)
Technical Committee on Ionizing Radiation (TCRI) since 2005 to strengthen the international network
in ionizing radiation standard measurement.

The SSDL of Nuklear Malaysia has been participating in the IAEA/WHO postal
thermoluminescent dosimeter (TLD) and postal ionization chamber intercomparison programme to
verify the accuracy of the secondary standard radiation source and ionization chambers used in the
calibration service in Malaysia. Samat et al. [11] reported that the SSDL of Nuklear Malaysia has
participated in this programme for 37 times since 1985 – 2008. Over a period of 28 years, the
laboratory has ensured that therapy-level dose within acceptance limits of 1.5% and 3.5% for postal
ionization chamber and TLD, respectively.

2. Materials and method
In the audit, the SSDL was provided with instruction and data sheets, a set of TLD (three capsules of
TLD in one set where two capsules to be irradiated and a control TLD) and the IAEA standard TLD
holder except in 2017 and 2019, the radiophotoluminescent dosimeter (RPLD) was provided. The
control dosimeter labeled with a white sticker uses to monitor background radiation, undesirable
accidental irradiation and unexpected fading.

Before irradiating the dosimeters, absorbed dose determination was performed according to the
IAEA’s TRS No. 398 code of practice with a calibrated 0.6 cm³ Farmer ionization chamber, type NE
2571 (PTW-Freiburg, Freiburg, Germany) connected to a PTW Unidos electrometer, type 10005 and
having a calibration in term of absorbed dose to water for ⁶⁰Co traceable to the IAEA Dosimetry
Laboratory (Figure 1). The water tank and waterproof sleeve for the chamber used are made of
Polymethylmethacrylate (PMMA) with density, ρ = 1.19 g/cm³. The water tank dimension is 30 cm x
30 cm x 30 cm. The thickness of the phantom wall is 1.5 cm. This water tank was designed with a 10
cm x 10 cm x 0.2 cm window for horizontal beam irradiation. The waterproof sleeve was fabricated
with a thickness of 0.2 cm to allow the chamber to achieve thermal equilibrium with the water in less
than 10 minutes and air gap of 0.2 cm to allow air pressure in the chamber to reach ambient air
pressure quickly.

![Figure 1. Measurement set-up for absorbed dose determination using the ⁶⁰Co. The ionization chamber is placed at 5 cm depth in water, 10 cm x 10 cm field size at the side wall of the water tank and 80 cm SSD.](image)

The SSDL were asked to irradiate the dosimeters with an absorbed dose to water of 200 cGy in
reference condition. Using a ⁶⁰Co teletherapy, the irradiation was carried out at 5 cm depth in water
with field size of 10 cm x 10 cm and source-surface distance (SSD) of 80 cm. For medical linear
accelerator, the irradiation was done at 10 cm depth in water with 10 cm x 10 cm field size at 100 cm
SSD (Figure 2).
Result of TLD audit was reported in the form of the percentage deviation between the SSDL stated dose and the IAEA measured dose where the acceptance limit of ± 3.5% should be complied. This value was calculated using equation 1.

\[
\text{Percentage deviation, } \Delta \% = \left( \frac{D_{\text{meas}} - D_{\text{SSDL}}}{D_{\text{SSDL}}} \right) \times 100
\]

where the \( D_{\text{SSDL}} \) is a mean measured dose by the IAEA from the readings of the TLDs irradiated by the SSDL and \( D_{\text{meas}} \) is the stated dose by the SSDL.

3. Results and discussion

A total number of 10 participations in the IAEA/WHO Postal Dose Quality Audit were recorded during 2009 to 2019 as presented in Table 1. Five participations using \( ^{60}\text{Co} \) teletherapy, three participations using 6 MV X-rays and 2 participations using 10 MV X-rays produced from medical linear accelerator. The SSDL were participated in the audit for one photon beam every year, except in 2018. The radiation unit used was a \( ^{60}\text{Co} \) teletherapy, type Eldorado 8 (Nordion, Ottawa, Canada) which belongs to Nuklear Malaysia and the medical linear accelerators were owned by the radiotherapy centres.

The results of the IAEA/WHO Postal Dose Audit from 2009 to 2019 performed by the SSDL are presented in Figure 3. The results demonstrate that the mean of percentage deviations between the SSDL stated dose and the IAEA mean measured dose was -0.35% with standard deviation of 0.86%. The percentage deviations vary between a minimum percentage deviation of -2.5% and a maximum of 0.6%. The mean of the distribution for \(^{60}\text{Co} \) was -0.50% and the standard deviation was 1.17%. For 6 MV X-rays, the mean of the distribution is 0.07% and the standard deviation is 0.01%. The result of the mean of the distribution for 10 MV X-rays is -0.60% and the standard deviation is 0.01%. All results were considered satisfactory in which complied with the IAEA’s acceptance limit of ± 3.5%. A percentage deviation with negative sign indicates that the SSDL estimates lower dose than what was measured by the IAEA. The uncertainties in the TLD and RPLD measurements of the dose were reported to be 1.8% and 1.5% (1 standard deviation), respectively.
Table 1. SSDL participations in the IAEA/WHO Postal Dose Audit from 2009 to 2019.

| Year of participation | Radiation unit         | Photon beam | 1.25 MeV 60Co | 6 MV X-rays | 10 MV X-rays |
|-----------------------|------------------------|-------------|---------------|-------------|--------------|
| 2009                  | Eldorado 8             |             |               |             |              |
| 2010                  | Eldorado 8             |             |               |             |              |
| 2011                  | Oncor Imp. +           |             |               |             |              |
| 2012                  | Varian Trilogy         |             |               |             |              |
| 2013                  | Varian Trilogy         |             |               |             |              |
| 2014                  | Eldorado 8             |             |               |             |              |
| 2015                  | Varian Trilogy         |             |               |             |              |
| 2016                  | Siemens Oncor Impression|             |               |             |              |
| 2017                  | Eldorado 8             |             |               |             |              |
| 2018                  | -                      |             |               |             |              |
| 2019                  | Eldorado 8             |             |               |             |              |
| **Total**             | **5**                  | **3**       | **2**         |             |              |

Figure 3. Summary of the results of the IAEA/WHO Postal Dose Quality Audit during 2009 to 2019. Data points represent the percentage deviation between SSDL stated dose and IAEA mean measured dose. The IAEA considers a result within ±3.5% to be satisfactory.

4. Conclusion
The results of SSDL of Nuklear Malaysia participated in the IAEA/WHO Postal Dose Quality Audit using 60Co teletherapy unit and medical linear accelerators have been presented. The results obtained from 2009 to 2019 demonstrate that all photon beams comply with the IAEA’s acceptance limit of ±3.5%. These audit results provide evidence that the SSDL of Nuklear Malaysia having a capability and competency in providing the calibration service of the radiotherapy dosemeter in compliance with the IAEA standard dosimetry protocols thus contributes to the improvement of quality of radiotherapy in Malaysia.
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