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Uncertainty estimation in Individual Monitoring – Part I

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Abstract

To achieve a good determination of the equivalent dose for occupational exposure workers from the whole body dosimeter an overall uncertainty associated the measurement need to be estimated. The work reported here is focused to estimate the absolute standard uncertainty arise for Reader Calibration Factor (RFC), Element Correction Coefficient (ECC) and Zero Dose Reading. In this study the thermoluminescence dosimeters are used and measured with Harshaw4500 Reader at Personal Dosimetry Laboratory in the Institute of Applied Nuclear Physics, Tirana, Albania and irradiated in Secondary Standard Dosimetry Laboratory (SSDL) in place. In this study we estimated the uncertainties coming from the measurements, and didn't take into consideration those which might arise from the users. The method used in this study is based on Guide to the Expression of Uncertainty in Measurement and ISO TR 62461 standard. The absolute standard uncertainty estimation for the RCF is found to be 0.0013nC/μSv, for the ECC is 0.032 and for the Zero Dose Reading is 0.1324nC. This study will be expand to include other important sources of uncertainties that influence the measurement, such as linearity correction factor, energy and angular correction factor, fading factor, temperature, environmental conditions, etc., in order to estimate the overall uncertainty arises from all these sources and to find which of the input quantities have the largest contribution on it.

Keywords: Absolute standard uncertainty, Reader calibration factor, Element correction coefficient, Zero dose reading, thermoluminescence dosimeters

Introduction

Occupational exposure due to radiation can occur as a result of the uses of radioactive sources in different human activities, such as in medicine, scientific research, education, agriculture and industry, nuclear fuel cycle facilities, etc. In order to control this exposure, it is necessary to be able to assess the magnitude of the doses for individuals involved in such activities [IAEA Safety Guide, No. RS-G-1.3]. Exposure estimation due to external radiation sources depends critically from the radiation type, energy and the conditions of the exposure. For an individual monitoring service is really important to provide accurate reports of the dose and to what extent the reported value is a good estimate of the true one. The greater the confidence interval or the probability that the measured value is within a defined range around the true value, the better the quality of the measurement. So, the process of determined the uncertainty which produces the best estimate of the quantity to be measured and may differ from the same quantity given by the instrument is an important one. This process can improve the result of the measurement by using different information beyond the indication of the instrument e.g. Tld Readers (energy and angle dependence, fading, etc.) in individual monitoring [IEC TR62461:2015]. The overall uncertainty in personal dosimetry is determined by the combined effects of both types of uncertainties, Type A and Type B. The objective of this study is to estimate the absolute standard uncertainties arise for Reader Calibration Factor (RFC), Element Correction Coefficient (ECC) and Zero Dose Reading. In this study we are going to estimate the uncertainties coming from the measurements, it doesn't take into consideration the uncertainties which might arise from the users.

Materials and methods

The personal dosimetry laboratory in the Institute of Applied Nuclear Physics is involved in providing personal dosimetry services at national level concerning the assessment of occupational exposure of all workers who works with ionizing radiation. In this study thermoluminescent detectors Tld-100 were used. The thermoluminescent dosimeters (Tld) consists of two detectors Lithium Fluoride (LiF:Mg,Ti) and are contained in a special holder to provide measurements of skin and deep doses. Lithium Fluoride based materials are near tissue equivalent and not light sensitive to provide confidence in handling the dosimeters and analyzing the results. A Sr-90 irradiator check source is used for QC analysis and the calibration process is done using the Secondary Standard Dosimetry Laboratory in place. Due to the various filters of the holder, one detector measures the depth dose Hp(10), and the other the surface dose Hp(0.07). The doses of the received Tlds are measured in the Harshaw4500 Reader by using hot nitrogen gas flow. The gas heating system uses a stream of hot nitrogen at precisely controlled, linearly ramped temperatures to a maximum of 300°C. The Tld cards are read and the records are processed by the WinREMS software.

The evaluated value of dose is obtain from the readout value given in nC from the Harshaw4500 Reader by applying the detector sensitivity coefficient, calibration coefficient, zero dose (blank indication) of the dosimeter. So the determination of the dose for whole body dosimeters is determined using the formula:

$$Hp(10)_i = \frac{(D_i - D_{av.0})}{(ECC_i * RCF)}$$

Where, Di is the measured value of the detector i in nC given by the Reader, Dav,0 is the average zero dose reading in nC, ECCi individual relative sensitivity of detector i (Element Correction Coefficient), RCF reader calibration factor in nC/μSv.

Uncertainties estimation

For uncertainty estimation we need a mathematical model function which states the relation of the input quantities X_i and the output quantity M [IEC 62461, (5.1.1)]. The dose in μSv is determined by using the model function:

(1) $$M_{corr.} = \frac{(D_{dose} - D_{av.\,zero})}{N_{RCF} \times k_{ECC}} \times k_{lin.} \times k_{E,\alpha}$$

Where, D_{dose} is the indication of the dosimeter in nC, $D_{av.\,zero}$ is the deviation due to zero indication of the dosemeter in nC, N_{RCF} is the reader calibration factor (nC/μSv), $k_{E,\alpha}$ is the correction factor for radiation energy and direction of radiation incidence, $k_{lin.}$ is the correction factor for linearity, k_{ECC} is the correction factor for element correction coefficient.

Uncertainty estimation for Reader Calibration Factor

The reader calibration factor (RCF) is found once per year using the Secondary Standard Dosimetry Laboratory (SSDL) in place. In our case to determine the calibration factor 5 Tlds were irradiated in the SSDL in place using Cs-137 radiation source, 0° incident radiation, for a given dose 5mSv, at 2m distance from the source. The calibration factor used for dose evaluation is determined by using the formula (2):

(2) $$RCF = \frac{Hp(10)_{av.}}{D_{ref.} * 1000} \left({}^{nC}/_{\mu Sv}\right)$$

The dose for each dosimeter $Hp(10)_i$ is calculated using the formula (3):

(3) $$Hp(10)_i = \frac{(D_i - D_{av.0})}{(ECC_i)}$$

Where, D_i is the dose measured for each dosimeter by the Harshaw Reader in nC, $D_{av,0}$ is the zero average dose, ECC_i is the Element Correction Coefficient for each dosimeter.

The absolute standard uncertainty u_{sRCFi} is associated with given parameters in the formula (2) and formula (3) and could be determined by using the absolute value of partial derivative of the functions with respect to the particular input quantity and standard uncertainties of the input quantities.

Therefore, the absolute standard uncertainty u_{sRCFi} is given by the geometrical sum of all contribution factors:

$$u_{sRCFi} = \frac{D_i - D_{av.0}}{ECC_i \times D_{ref.}} \sqrt{\frac{(u_{sDi})^2}{(D_i - D_{av.0})^2} + \frac{(u_{sDav.0})^2}{(D_i - D_{av.0})^2} + \frac{(u_{sDref.})^2}{(D_{ref.})^2} + \frac{(u_{sECCi})^2}{(ECC_i)^2}} = 0.00128\,\frac{nC}{\mu Sv}$$

Uncertainty estimation for ECC

For the determination of the Element Correction Coefficients (ECC) of dosimeters in routine monitoring the WinRems software is not being used, instead ECC's for each Tld is determined by a home developed procedure. According to the specific procedure Tld cards together with reference Tld cards are irradiated using the Sr-90 check source and measured accordingly, then the ECC factor has been calculated using Excel spreadsheet. In our case we have used 61 Tld cards, the mean value and the standard deviation is $ECC_{av.}$=1.047, s_{ECC}=0.09713, respectively and the absolute standard uncertainty of ECC is:

$$u_{s_{ECC}} = \frac{s_{ECC}}{3} = 0.032$$

Uncertainty estimation for zero dose reading

The determination procedure of zero dose reading of thermoluminescence dosimeters is an important parameter in order to correct for the additive doses arising from other sources than irradiation processes. It compromise the readout system background plus the intrinsic background of the detector. Intrinsic backgrounds of detectors can be determined for detectors individually or in batches specified in the IAEA Safety Standard [IAEA DS453, 2016, pg. 131 (7.128)].

The zero dose reading determining for a batch of dosimeters (intrinsic background of the detector), the dosimeters are measured at least twice after first reading. Then an average zero dose is calculated and this value is subtracted from the measurement dose reading. This average zero dose values are also used as a preliminary acceptance criteria for a Tld card. In our case we have used a batch of 19 Tld cards, the mean value of the zero dose and the standard deviation are $D_{av.zero}$=1.301nC, $s_{Dav.zero}$ =0.39706, respectively and the absolute standard uncertainty of zero dose reading is:

$$u_{s_{D_{av.\,zero}}} = \frac{s_{D_{av.\,zero}}}{3} = 0.13235nC$$

Conclusions

The definition of the measurement model as the key element for the uncertainty estimation and the identification of input quantities is very essential.

The absolute standard uncertainty estimation for RCF is found to be 0.0013nC/μSv, for the Element Correction Coefficient is 0.032 and for the zero dose reading is 0.1324nC; this three sources together with other ones will contribute to the overall uncertainty estimation of the measurement.

This study will be expand in order to include the other important sources of uncertainty that influence the measurement, such as linearity correction factor, energy and angle correction factor, measured value, fading factor, etc. in order to find the overall uncertainty.

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