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INFLUENCE OF REFERENCE FIELD SPECTRA ON CALIBRATION OF FIELD CLASS DOSIMETERS

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ABSTRACT

Active electronic dosimeters are usually calibrated in Secondary Standards Dosimetry Laboratories in reference photon fields, with the uncertainty which is typically around 5 % (k=2). Reference fields are established in accordance with relevant international standards – usually ISO 4037 for photon radiation. Some differences in spectra between different laboratories are unavoidable, but the effect on reference dose rates is well studied and within the above mentioned measurement uncertainty, and this is confirmed by existing interlaboratory comparisons. However, many field class dosimeters have poor energy dependence, especially in the energy range below 100 keV, which could cause large differences in calibration factors determined in different calibration laboratories under nominally the same conditions. This may also have implications for dosimeter testing or verification. In this paper, preliminary results obtained in two different calibration laboratories are presented.

1. Introduction

Active personal and ambient dosimeters are commonly used in radiation protection. Most of these instruments measure operational quantities such as personal dose equivalent and ambient dose equivalent, but in some countries other quantities are still used. These dosimeters are calibrated in most cases in Secondary Standards Dosimetry Laboratories (SSDL), which can usually provide measurement uncertainty of around 5 % (k=2). This measurement uncertainty represents the best measurement capabilities, and it is in most cases based on the calibration of reference class vented ionization chambers, which are high quality dosimeters built for use in laboratory conditions. However, field dosimeters are usually simpler and more robust, but on the other hand have worse metrological properties – including repeatability, linearity and energy dependence. Some dosimeters, such as non-compensated Geiger–Müller (GM) counters can have very high overresponse for low energy photons below 100 keV, by more than several hundred percent [1-3]. Most of the active personal dosimeters have energy dependence in accordance with relevant standards, but still the differences in response for different radiation qualities are usually several tens of percents [4]. The situation is similar with passive dosimeters, which can be used for personal and ambient monitoring, and can be compensated or non-compensated. Non-compensated passive dosimeters have energy dependence on par with non-compensated GM counters [5].

Use of these dosimeters in the field measurements, even when calibrated, can cause very high measurement uncertainties. Furthermore, pronounced energy dependence can cause calibration factors determined by different SSDLs to be significantly different, even though both SSDLs have nominally the same radiation qualities established and in compliance with relevant standards – usually ISO 4037-1 [6]. The conformity of established radiation qualities to the requirements of the standard is checked by participation in interlaboratory comparisons in terms of air kerma [7], or operational quantities (such as EURAMET DOSEtrace comparison [8]), which are conducted using vented ionization chambers, and by validation of radiation qualities, which is usually done by HVL measurements [6].

In this study, one ionization chamber will be calibrated by two different SSDLs to investigate the equivalence of calibration methods and measurement standards. In addition, several dosimeters with more or less pronounced energy dependence will also be calibrated by both laboratories, to see if the equivalence also holds for field class instruments. In this paper, calibration method is described and preliminary results are given.

2. Materials and methods

PTW 32005 ionization chamber with nominal volume of 27.9 cm3 was selected for comparison in terms of air kerma free-in-air. Air kerma calibrations are performed by substitution method, in comparison with national standards. Correction is performed for ambient temperature and pressure, and if necessary for leakage.

Comparison is also performed in terms of operational quantities, by using the same methods normally used for user dosimeters. Personal dosimeters that were selected are in conformance with IEC 61256 [9], meaning that the energy dependence of their response is between +67 % and -29 %, compared with the response for reference radiation quality (usually Cs-137). Several ambient dosimeters were selected with increasing energy dependence, including low-cost non-compensated GM-counters.

The comparison is performed in 8 radiation qualities, N-40 to N-200 and S-Cs (codes are from ISO 4037-1 [6], and S-Cs represents field of Cs-137 isotope). The overview of the used radiation qualities is given in Table 1.

Table 1. Radiation qualities used for interlaboratory comparison. Data are taken from ISO 4037-1, and actual values in SSDLs differ within the limits defined in the standard.

Radiation quality	**High Voltage** (kV)	**Mean Energy** (keV)	**1st HVL at 2.5 m** (mm)
N-40	40	33,3	2,63 Al
N-60	60	47,9	0,235 Cu
N-80	80	65,2	0,580 Cu
N-100	100	83,3	1,09 Cu
N-120	120	100	1,67 Cu
N-150	150	118	2,30 Cu
N-200	200	165	3,92 Cu
S-Cs	/	662	/

The comparison is performed in the following way: dosimeters are first calibrated in VINS, then in IMBiH, and then again in VINS, to check for long term stability and possible changes to the dosimeters, such as physical damage to the dosimeter components. Calibration coefficients (or factors) are compared for each dosimeter and for each radiation quality. At this moment, around half of the measurements have been completed.

3. Results and discussion

According to the preliminary results, significant difference was noticed between calibration factors for field class instruments in X-ray radiation qualities. Differences were much smaller in S-Cs radiation quality. There are two reasons for this difference: most dosimeters have much smaller energy dependence in the region around 662 keV, which is the energy of Cs-137. Also, radiation quality is much better defined for Cs-137 (single photon emission) than for X-ray radiation qualities (continuous spectra, validated by HVL measurements), and consequently the difference between SSDLs is much smaller. This also causes smaller differences for energy dependent field class dosimeters. The differences were much smaller for ionization chamber in all radiation qualities, and can be explained by measurement uncertainty.
Preliminary results for one dosimeter, based on 2 calibrations instead of 3, are given for a low-cost ambient dosimeter. Difference between calibration factors ranges between 3 % for Cs-137 (not statistically significant) and 25 % for N-40 radiation quality.

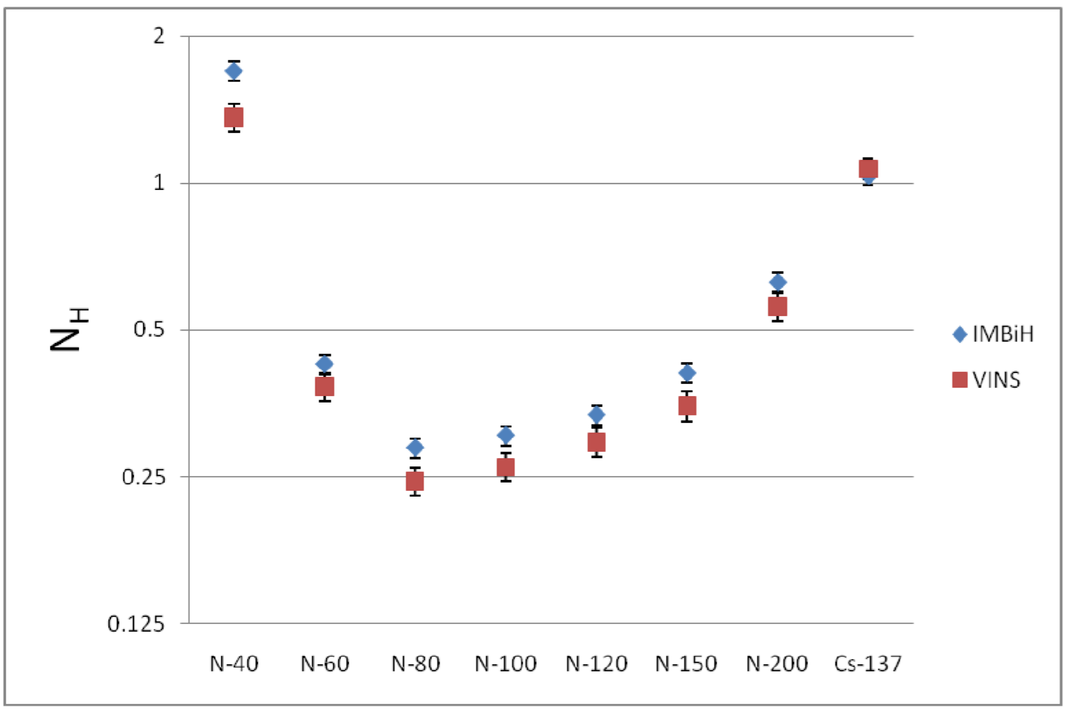

Fig.1 Comparison of calibration factors for a low cost ambient dosimeter.

4. Conclusion

It is very important to consider energy dependence of field class dosimeters, especially for low-cost or special purpose dosimeters. In some cases, the overresponse can be several hundred percent, and on the other hand, dosimeter might be unable to measure low energy photons, giving only background indication even when irradiated. In some cases, the energy dependence can be so high that even in reference conditions realized by SSDLs, calibration factors show significant differences. In such cases, additional uncertainty should be considered by users of the dosimeters, even if the dosimeters are used in known radiation fields (e.g. fields of known radionuclides). These problems are not as evident in Cs-137 field, which is most commonly used, due to the inherent spectral purity of such fields and due to the relatively flat energy response of most dosimeters in this region.

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UTICAJ SPEKTARA REFERENTNIH POLJA NA ETALONIRANJE KORISNIČKIH DOZIMETARA

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SADRŽAJ
Aktivni elektronski dozimetri se najčešće etaloniraju u Sekundarnim standardnim dozimetrijskim laboratorijama u referentnim poljima fotonskog zračenja, sa mernom nesigurnošću od oko 5 % (k=2). Referentna polja se uspostavljaju u skladu sa međunarodnim standardima, obično ISO 4037 za fotonsko zračenje. Male razlike u spektrima u različitim laboratorijama su neizbežne, ali je efekat na referentne vrednosti dobro proučen i ostaje u okviru mernih nesigurnosti, što je potvrđeno postojećim međulaboratorijskim poređenjima. Međutim, mnogi korisnički dozimetri imaju lošu energetsku zavisnost, pogotovo u opsegu energija ispod 100 keV, što može da uzrokuje velike razlike u kalibracionim faktorima određenim u različitim laboratorijama u nominalno istim uslovima. To može da ima posledice i na ispitivanje ili overavanje dozimetara. U ovom radu su prikazani prvi rezultati dobijeni u dve različite laboratorije za etaloniranje.