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ABSORBED DOSE TO WATER AND AIR KERMA RESULTS FOR MEASUREMENTS CARRIED OUT IN AN ONCOLOGY RADIOTHERAPY LABORATORY

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Abstract. This paper presents the comparison between the values for D_w (absorbed dose to water) and K_a (air kerma) measured with both the equipment of the Secondary Standard Dosimetry Laboratory at High Energy – STARDOOR [1], from The National Institute for Laser, Plasma & Radiation Physics – INFLPR and of the Radiotherapy Laboratory for High Energy of the "Prof. Dr. Al. Trestioreanu" Oncology Institute of Bucharest – IOB, following the TRS-398 [2] methodology. The measurements were performed at the Co-60 radiation source from IOB, in identical irradiation conditions. The results of these comparisons suggest that the real value for all measurements is in line with the accepted uncertainty limits. The E_n numbers (*i.e.* statistic performance) are $|E_n| \leq 1$ for each laboratory [3], both for D_w and K_a, assuring that the participant laboratories present a high degree of service quality.

Key words: air kerma, absorbed dose to water, secondary standard dosimetry laboratory, dosimetry comparison.

1. INTRODUCTION

According to specialized standards [4] a dosimetry laboratory must have quality control procedures for monitoring the undertaken calibrations and tests. This monitoring includes participation in comparisons or proficiency testing programs, regular use of reference materials or repeated calibration and tests using the same/different methods. By these means a laboratory can provide evidence of its proficiency to its customers and to the accreditation body. Interlaboratory comparison means organizing, conducting and evaluating the calibrations/tests using the same or similar objects for calibration/tests by two or more laboratories in accordance with predefined conditions.

The purpose of the comparisons, presented in this paper, is to validate the dosimetric system of STARDOOR laboratory, as to prove the quality of its services. Also, the comparisons were useful for the hospital dosimetry laboratory, to demonstrate that the radiotherapy for the patients is made according to the national legislation in force.

In these comparisons two physical parameters were selected: air kerma and absorbed dose to water, as to be measured and compared to the values obtained by the participating laboratories.

The STARDOOR laboratory is accredited by the Romanian Accreditation Body (RENAR), in January 2011 for undertaking calibration/testing of dosimetric devices/radiation generators [5]. Every laboratory takes part to the comparisons with its own dosimetric system. The values reported are those that include both the measured values and all corrections applied to obtain the correct values.

2. PARTICIPATING LABORATORIES, MATERIALS AND METHODS

The laboratory that confirmed its participation in the comparisons initiated by the STARDOOR laboratory was the Laboratory for High Energy Radiotherapy of the Institute of Oncology "Prof. Dr. Al. Trestioreanu", Bucharest.

Both the STARDOOR laboratory (INFLPR) and the IOB laboratory have written procedures for all the required tests, according to TRS-398. It is to be noted that the participants have at least 5 years of experience regarding the established tests. Before the actual tests were undertaken, the coordinator has evaluated the general and technical conditions available at radiotherapy laboratory of IOB. It was concluded that the participating laboratories fulfill the requirements regarding: the functionality of the management system, competence of specialists, work space, testing equipment and environmental conditions. The equipment was also checked for integrity and proper functionality. Also, the handling conditions were assured during the entire comparisons, as were the case of environmental conditions during the tests for every laboratory.

Fig. 1 – The Co-60 radiotherapy device Theratron 1000E type, of Radiotherapy Laboratory – IOB.

The work methods for the proposed tests are adopted according to TRS 398. For the type of measurements presented in this paper all types of radiation sources can be used: accelerators, X-ray generators [6], Co sources etc.

The ionizing radiation beam, with correction factor k_Q = 1.000, was supplied by the radiotherapy device with closed source Co-60, type Theratron 1000E (Fig. 1), of the Radiotherapy Laboratory of IOB. The activity of the gamma ray source on 10.11.1998 was of 481.2 TBq, according to the accompanying certificate and the Authorization of Use, issued by National Commission for Nuclear Activities Control (CNCAN).

The equipments used to testing by each laboratory are checked or calibrated as to assure traceability to national/international standards.

The used dosimetric measurement devices were: UNIDOS T10001 dosimeter serial number 10976 (Fig. 2) with a Farmer TN30001 ionizing chamber serial number 2373, belonging to the laboratory of IOB and UNIDOS T10005-50406 dosimeter serial number L137004 (Fig. 2) with a Farmer TN30010 ionizing chamber serial number 0445 belonging to the STARDOOR laboratory.

The two ionization chambers have identical technical specifications: vented sensitive volumes of 0.6 cm^3, designed for absolute photon and electron dosimetry [7] with therapy dosimeters; the wall material is graphite with a protective acrylic cover and the electrode is made of Al and the nominal photon energy range is from 30 keV to 50 MeV; the type 30001 ionization chambers the former model of the type 30010 [8].

Fig. 2 – The UNIDOS PTW dosimeters used for measuring air kerma and absorbed dose to water.

The UNIDOS reference dosimeter (owned by STARDOOR), can be used as secondary standard for calibration [9, 10], because it satisfies the requirements to be traceable to primary standard dosimetry laboratory, as it is periodically calibrated at the Physikalisch-Technischen Bundesanstalt (PTB) Germany.

The working conditions (temperature and pressure) were checked and recorded for each measurement, by using the OPUS 10, a device for measuring temperature and pressure. Over the entire period of the measurements the optimum conditions for manipulating the equipment were preserved, according to manufacturer recommendations. The equipment maintained its optimum working condition over the entire comparisons. At the end of the testing program, the equipment was handed over to the STARDOOR laboratory of INFLPR and to the Radiotherapy Laboratory of IOB.

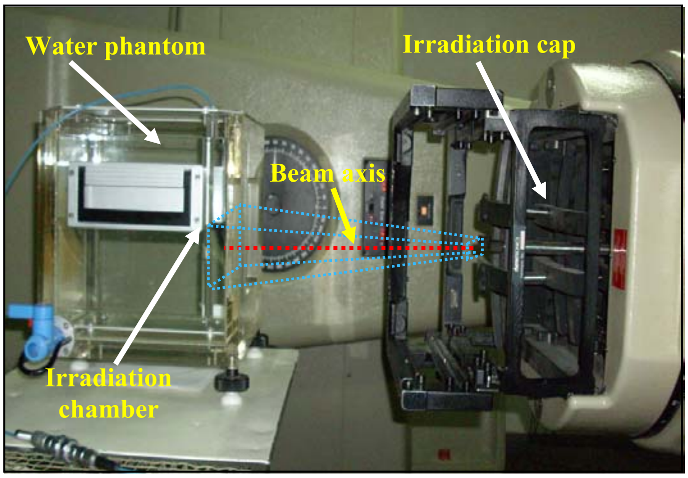

Fig. 3 – Irradiation geometry used to measure the absorbed dose to water.

For measuring the absorbed dose to water, a water phantom was used. The center of the ion chamber was positioned according to TRS 398, at 5 cm depth in water, as to assure a SCD (Source – Chamber Distance) = 100 cm and a SSD (Source – Surface Distance) = 95 cm, along the beam axis (Fig. 3). An irradiation field of 10 cm × 10 cm was set at the SCD level. Each of the participating laboratories took 30 measurements of the absorbed dose to water, with each measurement lasting 30 s. The temperature during the measurement period was de 22.1–22.2 ^{o}C and the pressure between 1014.7–1014.9 kPa.

For measuring the air kerma parameter, the center of the chamber was positioned at SCD = 100 cm from the source, along the beam axis. An irradiation field of 10 cm × 10 cm at the level of the ion chamber was set. Each of the participating laboratories took 30 measurements of the air kerma parameter, each measurement lasting 30 s.

Participating laboratories have reported the final values corrected for influencing factors.

3. RESULTS AND DISCUSSIONS

Evaluation of the results was performed in accordance with ISO 13528:2005[2]. An expert group was consulted and the program coordinators decided that none of the participating laboratories can be considered a reference laboratory, because of relatively similar conditions regarding the equipments used to testing and personnel. It was decided to apply the E_n numbers, which was the most relevant in this case. By applying the E_n numbers, a good consistency between data obtained by each laboratory was observed, not registering any aberrant values. During the measurements the conditions were kept as identical as possible between each laboratory.

Table 1

Mean values, medians, extended uncertainties, assigned real values, attributed assigned combined robust uncertainties and En numbers, calculated for the measured values of absorbed dose to water and air kerma

Parameter	Lab. 1: INFLPR	Lab. 2: IOB
The mean value for absorbed dose to water (D_w) corrected for all influencing factors [mGy]	213.23	213.50
The median for D_w value	213.34	213.34
Extended uncertainty (for k = 2)	2.03	3.02
The assigned real value of D_w [mGy]	213.37	213.37
The assigned combined robust uncertainty	0.17	0.17
E_n numbers	– 0.0386	0.043
The mean value for air kerma (K_a) corrected for all influencing factors [mGy]	215.72	215.75
The median for K_a value	215.75	215.75
Extended uncertainty (for k = 2)	2.22	2.40
The assigned real value of K_a [mGy]	215.75	215.75
The assigned combined robust uncertainty	0.49	0.49
E_n numbers	– 0.0135	– 0.00123

In calculating the uncertainty the IAEA-TECDOC-1585 [11] and TRS 398 standards were used. The combined uncertainty U_C ($U_C^2 = U_A^2 + U_B^2$) was taken into account. The type A uncertainty, U_A, was calculated using the average standard deviation.

From the results presented in Table 1, we conclude that the laboratories participating to the comparisons fulfill the required conditions in the field of radiation dosimetry.

The sources for the type B uncertainty, U_B, are as follows: a) the calibration of the dosimeter in a reference laboratory; b) the dosimeter resolution; c) the dosimeter stability; d) temperature measurement; e) the resolution of the temperature measurement; f) pressure measurement; g) deviations from the transverse position; h) the incidence angle of the radiation beam on the ion chamber; i) the distance between the radiation source and the ion chamber SCD; j) the irradiation head dimensions; k) source stability; l) position shifts of the source.

For every type B uncertainty, a uniform probability distribution (rectangular) was taken into account and the extend uncertainty was evaluated for a covering factor $k = 2$, which corresponds to a $P_\alpha = 95$ % confidence level.

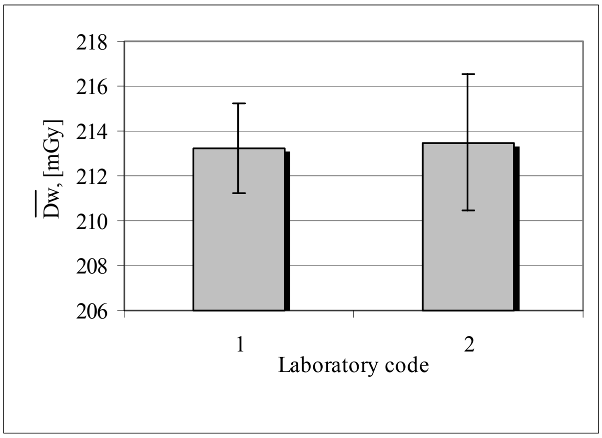

Fig. 4 – Representation for D_w mean values obtained by laboratory 1 and laboratory 2.

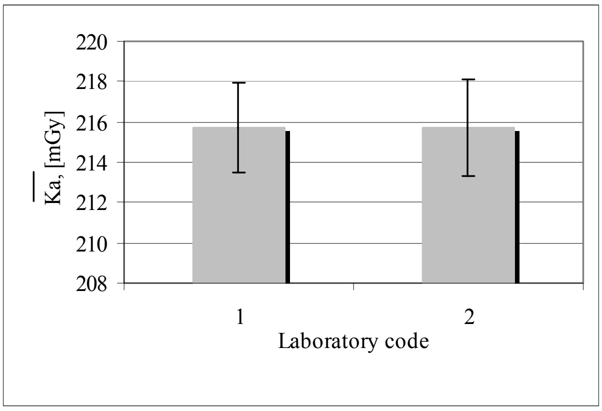

Fig. 5 – Representation of K_a mean values obtained by laboratory 1 and laboratory 2.

The E_n numbers for each laboratory was calculated according to ISO 13528:2005 (7.5. paragraph) and the assigned reference value was calculated according to algorithm C.1 described in the same standard. The condition that the measurement values are accepted is $|E_n| \leq 1$ which means that in the frame of a

Gauss distribution, 95.45 % of the E_n numbers would be inside the interval [–1; +1]. If the value of the E_n numbers is not within the interval, the laboratory in case is notified to take action to increase the E_n numbers.

For each set of measurements corresponding to air kerma and absorbed dose to water, the mean, standard deviation and combined uncertainty were calculated.

Figures 4 and 5 show the representations of the mean values D_w, respectively K_a, measured with each dosimetric system of the laboratories that participated in comparison, and include all correction factors. It can be observed that the two values are similar, the difference between laboratories being of 0.03 for K_a and 0.27 for D_w. Both values respect the imposed condition $|E_n| \leq 1$.

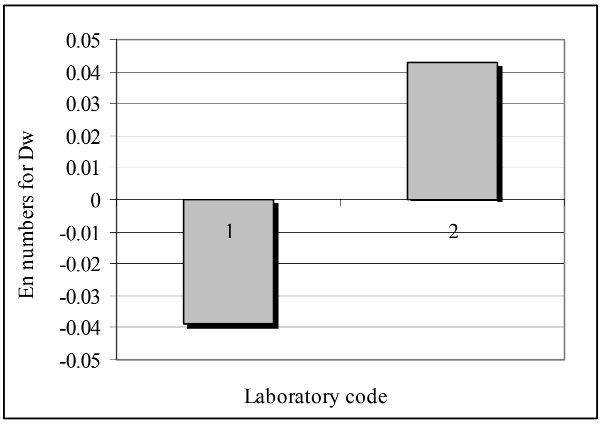

Fig. 6 – Representation of E_n numbers for D_w.

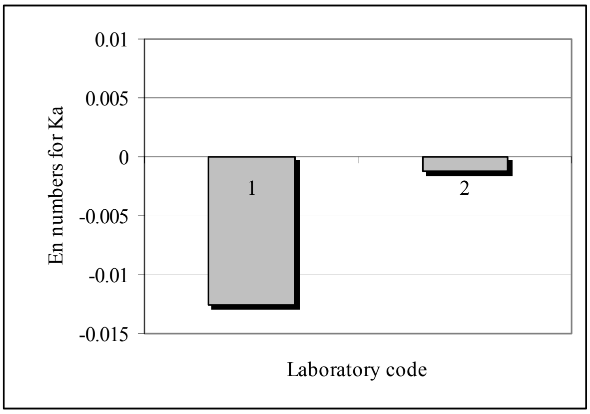

Fig. 7 – Representation of the E_n numbers for K_a.

Figures 6 and 7 show the representations of the E_n numbers calculated for K_a and D_w. The E_n numbers for the values air kerma and absorbed dose to water is within the imposed limits $|E_n| \le 1$, for each laboratory.

During the communication and information exchange between the participants, an adequate level of confidentiality has been assured regarding the people with access to the content of the documents (results reported by the participants, processing, reporting and archiving) as well as the way of sorting all documents and information.

4. CONCLUSIONS

The comparison results indicated that both participating laboratories meet imposed conditions. Thus, the real values for the measurements are within the limits of measurement uncertainty.

The E_n numbers for each laboratory, for the values air kerma and absorbed dose to water, comply with the limits $|E_n| \le 1$. Therefore the both participants have demonstrated that the quality control system implemented by each of them (though written procedures, qualified personnel, etc.) assure a high level of service quality.

The STARDOOR laboratory is aiming to undergo many intercomparisons with other national and foreign secondary standard laboratories as to demonstrate the quality of its services.

REFERENCES

1. F. Scarlat, A. Scarisoreanu, R. Minea, E. Badita, E. Sima, M. Dumitrascu, E. Stancu, C. Vancea, *Secondary standard dosimetry laboratory at INFLPR*, Optoelectronics and Advanced Materials – Rapid Communications **7** (7-8), 618-624 (2013).
2. International Atomic Energy Agency (IAEA), *Absorbed dose determination in external beam radiotherapy: An international code of practice for dosimetry based on standards of absorbed dose to water*, Technical Report Series no. TRS-398, Vienna, 2004.
3. ISO 13528:2005, *Statistical methods for use in proficiency testing by interlaboratory comparisons,* Geneva, Switzerland, 2005.
4. SR EN ISO/CEI 17025:2005, *General requirements for the competence of testing and calibration laboratories*, Romania, ASRO, 2005.
5. M. Dumitrascu, M. G. Albu Madalina, M. Virgolici, C. Vancea, V. Meltzer, *Characterization of electron beam irradiated polyvinylpyrrolidonedextran (PVP/DEX) blends*, Solid State Phenomena **188**, 102-108 (2012).
6. F. Scarlat, A. Scarisoreanu, N. Verga, *Absorbed dose distributions using the isodensitometric method for exposures with filter employed for mammographies*, Romanian Reports in Physics **65** (1), 168-177 (2013).
7. M. D. Stelescu, E. Manaila, G. Craciun, *Vulcanization of ethylene-propyleneterpolymer-based rubber mixtures by radiation processing*, Journal of Applied Polymer Science **128** (4), 2325-2336 (2013).
8. *Ionizing Radiation Product Catalogue*, Freiburg, Germany, PTW (2003/2004).

9. F. Scarlat, A. Scarisoreanu, M. Oane, E. Mitru, C. Avadanei, *On the absorbed dose determination method in high energy photon beams*, Proceedings of 6th Conference on Nuclear and Particle Physics, 485-494 (2008).
10. F. Scarlat, A. Scarisoreanu, E. Badita, E. Mitru, R. Vasilache, *Measurement with Hp(10) and H*(10) secondary standard chamber at NILPRP 7 MeV linear accelerator*, Radiation Measurements **45**, 1574-1577 (2010).
11. International Atomic Energy Agency (IAEA), *Measurement Uncertainty A Practical Guide for Secondary Standard Dosimetry Laboratories IAEA-TECDOC-1585*, Vienna, 2008.