Secondary Standard Dosimetry Laboratory in Central Laboratory for Radiological Protection in Poland

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Abstract

Central Laboratory for Radiological Protection (CLOR) has started measurements for establishing within its department a Secondary Standard Dosimetry Laboratory (SSDL). Taking into consideration Polish nuclear energy program as well as industrial, scientific and medical use of radiation it is highly recommended to ensure appropriate quality of a dosimetry monitoring. The planned SSDL will cover wide range of dosimetry calibration standards including already accredited methods of calibration with a use of standardized field of gamma and X-ray radiation as well as alfa and beta surface contamination sources and, additionally after adjusting to SSDL's requirements, Beta Secondary Standard (BSS-2) and Neutron Calibration stand with Am-Be source.

Presented work shows a conception of the planned development and validation of existing and newly implemented methods including part of realized Monte Carlo (MC) simulations designed to adequate a relocation of the stands within laboratory to minimize their influence on the quality of calibration process.

Key Words: monte carlo simulation, radiation protection, SSDL

1. Introduction

To ensure appropriate quality of a dosimetry monitoring, taking into consideration Polish nuclear energy program, Central Laboratory for Radiological Protection (CLOR) has started measurements for establishing within its department a Secondary Standard Dosimetry Laboratory[1] (SSDL). The planned SSDL will cover wide range of dosimetry calibration standards. It will remain in compliance with the methods already accredited by Polish Accreditation Centre. The accredited methods are operational in Laboratory for the Calibration of Dosimetry and Radon Instruments (LWPDiR). These methods refer to calibration with a use of standardized field of gamma and X-ray radiation as well as alfa and beta surface contamination sources. Additionally, Beta Secondary Standard (BSS-2) and Neutron Calibration stand with Am-Be source are planned to be adjust to SSDL's requirements.

Presented work shows a conception of the planned development and validation of existing and newly implemented methods including part of realized Monte Carlo (MC) simulations designed to adequate a relocation of the stands within laboratory to minimize their influence on the quality of calibration process. The planned SSDL will be established in two calibration labs: the first lab with a Gamma (Co-60, Cs-137, Am-241) and BSS2 (Sr-90, Kr-85) calibration stands whereas the second lab will include X-ray (N-40 ÷ N-300) and Neutron (Am-Be) stand.

Numerical simulations based upon MCNP/MCNPX code were commitment to cover two aspects of interest. The first case was to compare reference values of an air kerma measured by PTW ionization chamber type M23361 with UNIDOS electrometer with values given by MCNPX code. The second simulation was conducted to asses an influence on values of the ambient dose equivalent by attached to Neutron stand table.

2. Materials and methods

Two calibrations stands were examined in the framework of presenting work. Gamma Stand equipped with OB85/3 irradiator with three radioactive source Cs-137 (524 GBq), Co-60 () and Am-241 (). The calibrator i additionally equipped with three lead cylindrical absorbers with a thickness 1,85 (No. 1); 2,25 (No. 2) and 7,5 cm (No. 3). Gamma calibrator is placed on the one of two measuring hall (Gamma Hall) together with Surface Contamination Stand. The stand is additionally equipped on trolley with mounting system for calibrated instruments and laser based positioning system. The distance from the source in measured by laser distance meter with accuracy of 1mm. Second a Neutron Stand with OB26 calibrator containing Am-Be (185 GBq) source is placed together with X-ray Stand and BSS-2 on the another calibration hall (RTG Hall).

For air kerma measurements PTW UNIDOS electrometer with PTW type 23361 chamber calibrated in Polish Primary Standard Laboratory was used. The chamber is a cylinder with active volume of 30 cm^3. Measurements of references values of air kerma were made without additional buld-up cup. The voltage was set to +300V. For Gamma Stand MC simulation have been made using MCNPX ver 2.7.0[2] code. Results of simulations were F4 tally (flux averaged over a cell) multiplied by fluence-to-kerma conversion coefficients basing on ICRU 57[3] and ENDF/B-VI Release 8 cross-section files. Final values of air kerma were obtained according to equation:

$$K_a = F4 \cdot A \cdot Y \cdot 3.6 \cdot 10^{-6}$$

where, K_a is in mGy/h, *F4* is a results of F4 tally corrected by ICRU coefficients, *A* is a activity of the source in Bq, *Y* is a yield of gammas at energy 661,7 keV emitted by Cs-137 source.

For neutron calculation MCNP5[4,5] code was used. Comparison of neutron flux at point detector, tally F5, for two configurations with and without calibration table were made. The main material of the table is steel because of that it was represented in the simulation as a plate steel cylinder that well reflect a real situation. Obtained results of ambient dose equivalent rate, $\dot{H}^*(10)$ [μSv/h] were based on conversion factors from ICRU 57 and value of total neutron emission from the source equal $1{,}1 \cdot 10^7$ n/s according to the manufacturer documentation[6].

3. Results

Values of air kerma were measured at three Source-Chamber Distances (SCD) 83, 100 and 150 cm, additionally at 150 cm absorber No. 1 was used. For the same conditions Monte Carlo simulation was performed, results presents Table 1. Model for MC simulation consisted only a lead part of the irradiator and the chamber put in the air, see Figure 1. For considered measuring points maximum difference reached 1,4 % what shows a good agreements between two methods.

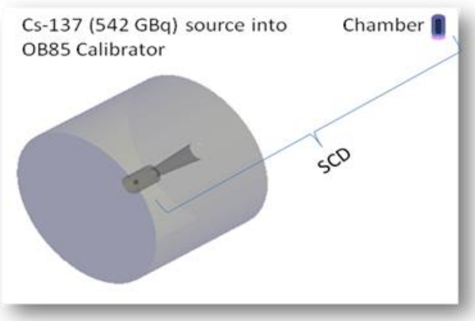

Figure 1 Model of the Gamma Stand for MC simulation

Table1 Results of measurements and MC calculation for Gamma Stand, source Cs-137.

SCD, cm	Absorber, cm Pb	UNIDOS, mGy/h	MCNPX, mGy/h	Difference, %
83	0	54.75	55.50	1.4
100	0	37.80	37.87	0.2
150	2.25	1.23	1.21	1.0

For Neutron Stand MC simulations with two different configuration were performed. First included neutron calibrator OB26 and a calibration table as was shown at Figure 2.

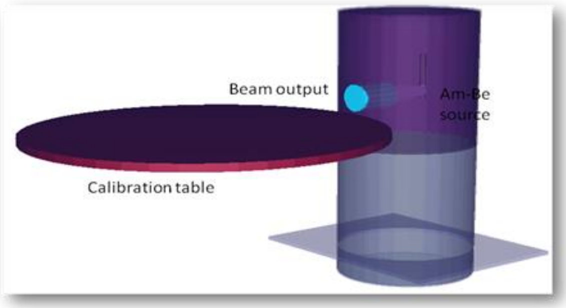

Figure 2 MC geometry of the Neutron OB26 irradiator with calibration table.

Performed simulations shows that the differences in $\dot{H}^*(10)$ for two mentioned geometries depend on the distance from the source, as farther from the source as smaller differences we could expect. Results for seven distances shows Table 2. Additionally obtained results were compared with results for identical OB26 irradiator made by Mazrou[7] et al.

Table 2 Differences in $\dot{H}^*(10)$ for two configuration and result for similar irradiator

Distans source - detector [cm]	100	150	200	250	300	350	400
				Configuration with calibration table			
H*(10) [µSv/h]	210,0	88,7	46,7	28,4	19,3	14,0	10,7
				Configuration without calibration table			
H*(10) [µSv/h]	186,1	78,9	43,5	27,5	19,0	13,9	10,7
Difference, %	11,4	11,1	6,9	3,2	1,4	0,6	0,04
				Only OB26 Irradiator			
Mazrou, H.	125,8	55,9	31,5	20,1	14	10,3	7,9

4. Discussion and perspective

The simulations that were carried out shows Monte Carlo technique is a good equipment in the process of designing of the laboratories using radioactive sources. MCNP5/MCNPX looks to be a universal tool both to gamma and neutron simulations purposes. The presented work is a preliminary for the next investigation in the subject of SSDL establishment in Central Laboratory for Radiological Protection. Next step will be do into the measurements of the neutron flux by adequate instruments, and more complex geometries with all infrastructure of the lab.

5. Conclusions

CLOR's Laboratory is equipped with X-ray, gamma, beta (BSS-2) and neutron source. Monte Carlo (MC) simulations to adequate a relocation of the stands within laboratory to minimize their influence on the quality of calibration process were designed. Good agreement between measured and calculated values of air kerma rate for Gamma Stand proving small influence of hall infrastructure for calibration results – no need for additional changes in hall organization. High influence of the neutron calibration table for the neutron fluence in a measuring point – replacement of the table is being considered . SSDL's requirements for each of the calibration standards must be defined and fulfilled. Establishing SSDL in CLOR will improve the dosimetry monitoring in the current activities and future needs regarding nuclear energy program.

6. Acknowledgments

This work/article presents results of the SPREJ project entitled "Development of methods for ensuring nuclear safety and radiological protection for current and future needs of nuclear power plants" supported by a grant from the National Centre for Research and Development (NCBiR).

References

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[1] SSDL Network Charter, IAEA, Viena, 1999

[2] Pelowitz Denise B., editor, MCNPX User's Manual Version 2.7.0, LA-CP-11-00438, April 2011,

[3] Conversion Coefficients for use in Radiological Protection Against External Radiation, ICRU Report No. 57, 1998

[4] MCNP-A General Monte Carlo N-Particle Transport Code, Version 5, Volume I: Overview and Theory, X-5 Monte Carlo Team, April 24, 2003 (Revised 2/1/2008). Los Alamos National Laboratory

[5] MCNP-A General Monte Carlo N-Particle Transport Code, Version 5, Volume II: Overview User's Guide, X-5 Monte Carlo Team, April 24, 2003 (Revised 10/3/2005, 2/1/2008). Los Alamos National Laboratory

[6] Technical Documentation of the OB26 calibrator, 1998

[7] Mazrou H., Sidahmed T., Allab M., Neutron Field Characterisation Of The OB26 CRNA Irradiator In View Of Its Use For Calibration Purposes, Rad. Prot. Dosim., Vol 141, No. 2, pp. 114-126