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The stability and Quality Control of Instruments for Measurement of Ambient Dose Equivalent Rate

Jelena Krneta Nikolić*, Marija Janković, Milica Rajačić, Ivana Vukanac, Dragana Todorović and Nataša Sarap

***Abstract* — Dosimeters for ambient dose equivalent rate monitoring used in Radiation and Environmental Protection Department in the Institute for Nuclear Sciences Vinča, are made inhouse and they are readily exploited in the field work. Due to this and due to the nature of the measurement itself, quality control of these instruments is readily performed, at least 2 times per year. The control is performed using a ^{60}Co closed point source with the original protective lead casing and an absorber placed over it in order to mimic the real measurement dose levels. Mean value of the ratio of the first 10 consecutive measurements and the activity of the source on the day of the measurement is declared as a baseline value, while the standard deviation of these 10 values was used to establish the limits of acceptance. According to the analysis of the first two years of the quality control, it can be concluded that all three types of instruments show satisfactory stability.**

***Index Terms* — ambient dose equivalent rate monitors; quality control; measurement stability; dosimetry**

I. Introduction

Measurement of ambient dose equivalent rate is a measurement method readily used in Radiation and Environmental Protection Department in the Institute for Nuclear Sciences Vinča. This method is accredited with the Accreditation Body of Republic of Serbia under the Standard 17025/2017 [1]. In that sense, it has to comply with the Quality control management system of the Department. Quality control should be planned activity, described in the quality control documentation, performed in a systematic manner, recorded and reviewed. Planning should identify and define type and frequency of quality control, acceptance limits, actions if those limits are exceeded and periodic review of results.

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Dosimeters for ambient dose equivalent rate monitoring used in Radiation and Environmental Protection Department in the Institute for Nuclear Sciences Vinča, are made inhouse and they are readily exploited in the field work. Due to this and due to the nature of the measurement itself, it is decided that the quality controll has to be performed at least 2 times per year. As a result of these periodic quality controll measurements, Shewhart control charts, which span over a period of 2 years from mid 2020 to mid 2022, are revised in terms of the stabiity of the instruments' performance. In this paper, the analysis of these Shewhart control charts is presented for 3 types of dosimeters used in Radiation and Environmental Protection Department.

II. Main Results and Discussion

In the Radiation and Environmental Protection Department of the Institute for Nuclear Sciences Vinča, following types of instruments are readily used and controlled: MOKO-100, RMK 10/RMK-10P and RADEX RDI (total of 10 instruments).

Many of investigated ambient monitors have indication directly in Sv/h, but other instruments have indication in counts per second (cps) and the values in terms of ambient dose equivalent need to be calculated based on the calibration [2]. Also the ones that have an indication in µSvh-1 have to be calibrated and the calibration coefficient established. The calibration is performed in the Secondary Standards Calibration Laboratory in the Radiation and Environmental Protection Department by using the sources with the defined radiation quality, angle of incidence and dose rate. Calibration coefficient is then defined as the ratio of the refrence value and the indication of the instrument. The calibration coefficient with the appropriate measurement uncertainty is stated in a Calibration certificate [3,4].

The quality controll of the instruments is performed every 3 – 6 months, depndent on the availability of the instrument at each particular moment.

The controll is perfomend using a ^{60}Co closed point source, product number 9031-OL-591/09 with activity of 732.9 kBq on 01.08.2011, produced by Czech Metrology Institute. The source was kept in the original protective lead casing and an absorber was placed over it. Absorber is a 12 high cylinder made of polystyrene, which provides that the

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dose rate originating from the source is not too high. This source and setup were chosen because the dose rate corresponds to the conditions occurring in routine dosimetry measurements. The measurement method was validated by comparing the results of a measurement of the same ^{60}Co closed point source using investigated instruments and other types of instrument that are already in the Quality Management System.

For establishing the baseline, a set of 10 consecutive measurements was performed with each investigated instrument. Since the quality control measurements should be performed over a long period of time, it has to be taken into account that the activity of the source will decrease. Logically, the measured values will decrease also. This is why it was chosen that, instead of a direct result obtained by the instrument, a ratio between the measurement result and the activity of the source on the date of measurement should be used as a value to be regarded.

Mean value of the ratio of the first 10 measurements and the activity of the source on the day of the measurement is declared as a baseline value, while the standard deviation of these 10 values was used to establish the limits of acceptance. As it is usual, the limits of acceptance were set on ±2σ, the warning interval was set to be between ±2σ and ±3σ, while the results that exceed the limits of ±3σ should be regarded as not satisfactory.

A. Results and Discussion

The quality control of the instruments was perfomed 6 times for most of the instruments in the period from mid 2020 to mid 2022. The procedure included performing of 5 consecutive measurements, applying the calibration factor to the mean value and calcuating the ratio between the mean value of 5 measured ambient dose equivalent dose rates and the activity of the source at the day of the measurement. For each instrument, a Shewhart control chart was made and the stability of the measurement results in time was followed. In Table 1, the range of quality control measurement for all instruments is presented along with the baseline ratio expressed in %. As it was said before, the baseline value was obtained by performing 10 consecutive measurements at the beginning of the quality control period.

As it can be seen from the Table 1, all instruments showed results that do not differ significantly from the baseline. In all Shewart charts, the limit of ±2σ was not exceeded. Since the measurement uncertainty of the results obrtained by the ambient dose equivalent rate monitors can be up to 30% [3, 5], the ranges can be considered as a relatively narrow. The difference between the maximum and minimum ratio obtained during the quality control measurements was below 15% for all controlled monitors. This means that the limits of acceptance for the stability and reproducibility of the measurements are more strict than the measurement uncertainty of any single measurement, showing the satisfactory stability of the repeated quality control measurements.

TABLE I
RANGE AND OF THE OBTAINED MEASURED DOSE [μSVH-1]/ SOURCE CTIVITY [BQ] AND BASELINE - MEAN VALUE OF FOR THE FIRST 10 MEASUREMENTS

Instrument	Range Measured dose/source activity [%]	Mean value of Measured dose/source activity ratio for the first 10 measurements [%]
MOKO 100 s/No. 250214	1.084-1.109	1.1
MOKO 100 s/No. 002	0.985-1.049	1.0
MOKO 100 s/No. 1802	0.924-0.975	0.90
MOKO 100 s/No. 0604-02	0.914-0.976	0.92
RMK 10P s/No. 0549	0.857-0.897	0.91
RMK 10P s/No. 0309	0.096-1.07	1.01
RADEX RDI1706 s/No. 0711259A7115 72	0.872-1.01	0.95
RADEX RDI1706 s/No. 0711259A7115 74	0.942-1.002	0.97
RADEX RDI1706 s/No. 0711259A7115 70	0.943-1.028	0.98

Figures 1, 2 and 3 show unified Shewards charts for the three different types of ambient dose equivalent rate monitors. In order to present different instruments on the same chart, the baseline was established as the mean value of all single baselines of each instrument. The limits were established using the standard deviation of the baselines of individual instruments. In this way, the limits of acceptance have become even more narrow, giving the very strict criterion for the stability of measurements. Here we can observe the behaviour of different types of monitors. All tree types showed satisfactory stability of the ambient dose equivalent rate/source activity ratio, since in no case was the limit of ±2σ exceeded. RMK type of monitors showed the gratest stability of the measurement while MOKO 100 and RADEX showed wider spread of the results. This however does not mean that there is an advantage of one type of instrument over the other, since the period of the quality control, as well as the number of performed measurements is not equal for all types and not large enough for more in depth analysis. Also, for MOKO 100 instrumets, the limits of acceptance are very narrow, more so than for other two types of instruments. However, since the quality control measurements are performed in the controlled environment, using the radioactve source of the defined geometry, setting stict limits of acceptance is not unwaranted. The stability of the measurement in the controlled situation can be considered as a good predictor of the stability in the real measurement circumstances.

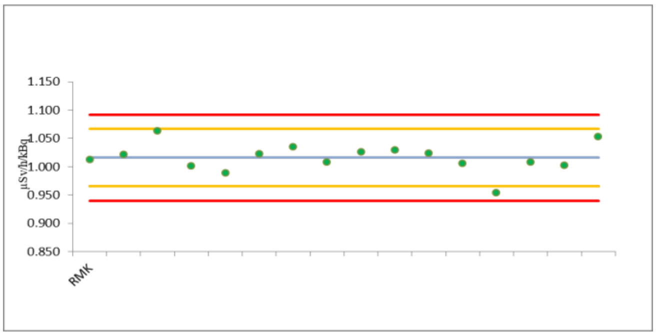

Fig. 1. Unified Sheward chart for 3 RMK 10 type of ambient dose equivalent rate monitors

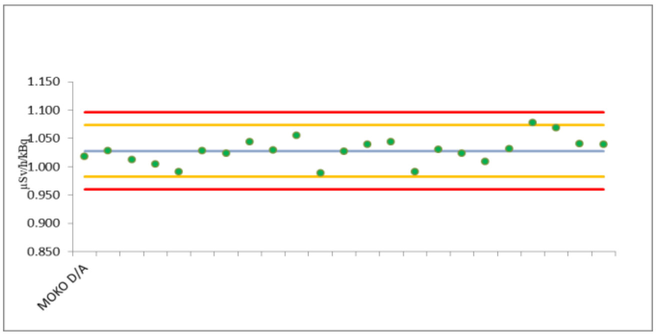

Fig. 2. Unified Sheward chart for 4 MOKO 100 type of ambient dose equivalent rate monitors

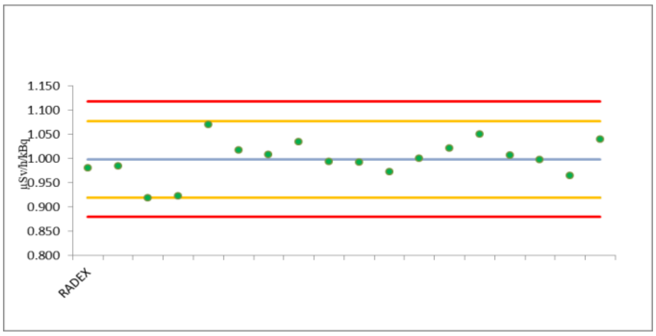

Fig. 2. Unified Sheward chart for 3 RADEX type of ambient dose equivalent rate monitors

III. Conclusion

In this paper we presented the analysis of the quality control measurements and stability of the measurement for 3 types of ambient dose equivalent rate monitors (10 monitors in total) readily used in Radiation and Environmental Protection Department. The period of quality control was from the mid 2020 to mid 2022. All 10 investigated instrument were periodically controlled and Sheward charts readily analyzed in order to assertain the stability of the performance. According to the analysis of the first two years of the quality controll, it can be concluded that all three types of instruments shhow satisfactory stability. Analysing the performance of individual monitors, it can be seen that the difference from the baseline is less than 15% and that the limits of acceptance were never exceeded. Looking at the unified Sheward charts, it can be consluded that neither type of monitor can be singled out as a more or less stable during this period. Since the quality control of these monitors is a mandatory part of the accredited method of measurement, this kind of analysis and controll will be continued in the future, giving more useful data and more opportunities for improvement.

Acknowledgment

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