Simulated Surface Contamination Measurement for the IAEA – TERC – 2022 - 01/02 Proficiency Test

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***Abstract* — As a part of regular activities of the accredited laboratory, the Laboratory for Radiation Measurements of the Radiation and Environmental Protection Department, Institute Vinča, every year takes part in the proficiency tests organized by IAEA. This year, within the framework of IAEA – TERC – 2022 – 01/02 Proficiency Test, one of the requests was to measure the simulated surface contamination using the instrument that are at the disposal in the participant laboratories. The results should be reported in the units of counts/s/cm² in order to be comparable. In this paper, the measurement method and subsequent specific calculations for the simulated surface contamination are explained and the results of the proficiency test stated and discussed.**

***Index Terms* — handheld dosimeter; surface contamination; proficiency test; dosimetry**

I. Introduction

As an accredited laboratory, the Laboratory for Radiation Measurements of the Radiation and Environment Protection Department is required to participate in a certain number of proficiency tests and interlaboratory intercomarisons for all the measurement methods that are within the scope of the accreditation. One of these methods is measurement of ambient dose equivalent. International Agency for Atomic Energy (IAEA) readily organizes proficiency tests and in later years, the analysis of simulated contamination is included in the proficiency test requirement.

In the year 2022, IAEA provided a proficiency test where, among other things, a simulated surface contamination was to be measured. A 10 cm x 15 cm rectangle was printed (blue ink) on a matte polyester canvas carrier material. A blank sample of the same size has been provided also. The sample was to be measured using a portable surface contamination monitor for alpha and beta surface emission rate and the results reported in the units counts/s/cm². The radioactive content of these samples was higher than the normal environmental level, in order to be detectable by portable surface contamination monitors. It is indicated further, in the reporting requirements, that the surface contamination contains ^{239}Pu as an alpha emitter and ^{137}Cs as a beta emitter [1].

In this paper, the measurement procedure as well as the calculation of the results is presented. The reported results were then compared to the target values provided by the IAEA using the criteria defined also by the IAEA in order to ascertain whether the results are in accordance with the target value in terms of the accuracy and the precision.

II. Main Results and Discussion

The participants of the Proficiency Test were provided with two matte polyester canvas filter papers that are to be measured. One is printed with the paint containing an unknown activity, representing the simulated surface contamination and he other was blank filter paper, meant to serve for a background measurements. The dimensions of the filter papers were 10 cm x 15 cm.

For the measurement, handheld contamination probe 6150AD-k, with dose rate meter 6150AD was used. The probe 6150AD-k uses a large area proportional counting tube as a detector with the aluminum foil window. The counting tube is sealed and does not require refilling or flushing from external gas reservoirs. The filling already present in the instrument is a mixture of inert gases which is not inflammable and thus does not represent any fire or explosion hazard. The aluminum foil has a thickness of approximately 2.8 mg/cm² and is supported by a grille above and the additional fine etched mesh grille which protects the foil [2].

The probe 6150AD-k has two operating modes: “alpha” and “alpha-beta-gamma” which can be selected through the switch on the probe, the two positions which are marked “a” and “abg”. In mode “a” the counting tube operates at reduced high voltage and is therefore sensitive to alpha radiation only. In mode “abg” all three kinds of radiation will be detected. Also, this probe has a discriminator plate which is a metallic plate that blocks alpha and beta particles and is therefore used to provide the option of measurement of only gamma radiation.

The efficiency (or better said the activity response) of the probe is defined as $\varepsilon_{4\pi}=n/A$, where n is a count rate generated in the instrument and A is the activity of the

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source. The term 4π refers to the geometry, where all the particles emitted from the source, both in the upper and lower solid angle are taken into account. Efficiency $\varepsilon_{4\pi}$ converts the net count rate n into activity A underneath the detector area. On the other hand, calibration factor C_S converts the net count rate n into surface related activity A_S averaged across the detector area W:

$$A_S[Bq/cm^2] = C_S \cdot n$$
$$A_S = A/W \Rightarrow C_S = \frac{1}{\varepsilon_{4\pi} \cdot W} \tag{1}$$

Provided that the efficiency is determined by measuring the known surface contamination, it is possible to obtain the calibration factor needed to calculate the unknown surface contamination directly from the measured count n and it will be expressed in counts/s/cm^2. In the Table I, the efficiencies obtained as explained and appropriate calibration factors are listed, as given in [2].

TABLE I
CALIBRATION FACTORS C_S AND EFFICIENCIES $\varepsilon_{4\pi}$ FOR THE PROBE 6150AD-k (DETECTOR AREA 170 cm^2) [2]

Radionuclide	**Radiation type/ energy [Mev]**	**Mode**	$\varepsilon_{4\pi}$	C_s
^{241}Am	α / 5.5	α	0.08	0.074
		αβγ	0.105	0.056
^{238}U	α / 4.2-4.8	α	0.028	0.21
		αβγ	0.40	0.015
^{14}C	β / 0.15	αβγ	0.032	0.182
^{60}Co	β / 0.32		0.10	0.058
^{137}Cs	β / 0.51		0.23	0.026
^{36}Cl	β / 0.71		0.23	0.026
^{90}Sr/^{90}Y	β / 0.54-2.3		0.54	0.011
^{60}Co	γ / 1.25		0.0115	0.51
^{137}Cs	γ / 0.66		0.0022	2.69

A. *Results and Discussion*

Total of 10 measurement were made on both the contaminated filter paper and blank filter paper. Alpha (“a” mode) and alpha-beta-gamma (“abg” mode) measurements were performed with the discriminator plate removed, whereas gamma measurements were performed with the discriminator plate applied to suppress alpha and beta radiation. The gap between the probe and the reference source was as small as the shape of the sources and the probe allowed for. The count for beta particles was obtained by subtracting the count for alpha and gamma from the alpha-beta-gamma count.

The number of detected particles n, was obtained as the mean value of 10 measurements and the mean value of the blank measurements was subtracted. The appropriate standard deviation was taken as the measurement uncertainty. Since the surface of the filter paper was smaller than the surface of the probe (150 cm^2 versus 170 cm^2), the obtained count was corrected for the ratio between the two surfaces.

Since it was concluded, based on the instructions provided for the proficiency test, that the beta emitter in the surface contamination was ^{137}Cs, the appropriate calibration factor of 0.026 could be taken from [2], as listed in the Table I. Since there are no defined calibration factor for alpha emitter ^{239}Pu, the calibration factor for ^{241}Am was taken, since the energy of alpha particles from the two radionuclides was similar. Then, the surface contamination was calculated by simply multiplying the net count, corrected for the background and surface ratio, with the calibration factor.

The Z- score criterion was used to evaluate the reported results. A robust mean of all reported results was used as a target value and the Z – score was derived by the following equation [1]:

$$Z = \frac{Value_{reported} - Value_{target}}{s^*} \tag{2}$$
$$s^* = 1.483 \cdot median\left|Value_{reported} - Value_{target}\right|$$

where s* is the robust standard deviation without refinement.

In the Table II, the reported results, target value and the evaluation of the results is presented.

TABLE II
REPORTED RESULTS, TARGET VALUES, Z-SCORE AND EVALUATION OF THE SIMULATED SURFACE CONTAMINATION RESULTS

	Reported value [counts/s/cm^2]	**Target value [counts/s/cm^2]**	***Z-score***	**Evaluation**
gross alpha	0.105 ± 0.033	0.081 ± 0.052	0.46	A
gross beta	0.17 ± 0.03	0.158 ± 0.084	0.14	A

As it can be seen from the Table II, both gross alpha and gross beta values were acceptable. Also, the reported uncertainty was of the same order of magnitude as the target uncertainty obtained as the robust standard deviation without refinement. This shows that the measurement conducted at the laboratory was at the same grade of precision as all the other participant laboratories that reported the results for the simulated surface contamination. The reported and target values do not differ within the measurement uncertainty reported, thus confirming the accuracy of the results.

III. CONCLUSION

In this paper we presented the measurement method and the calculation procedure applied for the measurement of the simulated surface contamination, that was requested within the framework of the IAEA – TERC – 2022 – 01/02

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Proficiency Test. since the request of the proficiency test was to express the results in counts/s/cm^2, the usual method of calculation of the surface activity had to be modified.

The gross alpha and gross beta measurement was conducted using handheld contamination probe 6150AD-k. Total of 10 measurement were made on both the contaminated filter paper and blank filter paper. The calibration factor that converts the net count rate n into surface related activity A_S averaged across the detector area W was taken from the User manual of the handheld probe. The reported results, together with the standard deviation were found to be acceptable according to the Z – score test. Also the accuracy and the precision of the results were acceptable since they did not differ significantly from the target values provided by the IAEA.

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