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Note

Performance of surface contamination monitors in alpha and beta radiation fields

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1. Introduction

Radioactive surface contamination consists of unwanted radioactive material deposited in an uncontrolled manner in or on animate or inanimate objects, irrespective of their situations, in such concentrations that either an operational inconvenience or a radiological hazard is caused (TRS 1970). The aim of measuring surface contamination is to detect the contamination and its extent, and afterwards to evaluate the activity per unit area in order to verify that the permissible limits are not being exceeded.

The most common instruments used for surface contamination detection are scintillators, proportional counters, semi-conductor detectors and Geiger-Müller detectors provided with thin entrance windows (TRS 1970, Oberhofer 1983). The choice of the instrument should depend on assessment of the parameters that could affect the surface contamination measurement. These are: the area to be monitored, the radionuclides present, the contamination level and the background radiation. Each instrument should be calibrated and its performance checked in a standard laboratory before its first use, after each repair, and then be recalibrated periodically, usually every 12 months (TRS 1970, CNEN 1988). The calibration process of such instruments involves the use of different radioactive standard sources (ISO 1988a, b).

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In this work, the responses of a scintillator, a proportional counter and two Geiger-Müller detectors were studied in standard alpha and beta radiation beams, and their efficiency was determined.

2. Materials and methods

The proportional counter IEN, model PA-01B (Brazil), and the alpha probe scintillator Nardeaux, model SIA 7-1 (France) were tested connected to the measuring unit IEN model 7018 (Brazil) and to the measuring unit Nardeaux model IPAB 7-1 (France) respectively. The proportional counter has an active area of 78 cm² and an aluminised Mylar entrance window (0.7 mg cm⁻²) and the scintillator has an active area of 30 cm² and an aluminium screen (0.8 mg cm⁻²).

The Geiger-Müller detectors (pancake type), Eberline model HP 210AL (USA) and IEN 018 model 7A003 (Brazil), were connected to the IPEN measuring unit, model PI-31 (Brazil). Both detectors present active areas with a 5 cm diameter. The readings were taken at intervals of 1 min.

The secondary standard alpha radiation set was composed of ²³⁹Pu, ²³⁸Pu, ²⁴⁴Cm, ²³³U and ²⁴¹Am sources (diameter 15 mm), with calibration certificates of the Laboratoire de Métrologie des Rayonnements Ionisants (LMRI), France, and by ²⁴¹Am sources (diameter 8 mm) produced and calibrated at the Nuclear Metrology Laboratory of

IPEN (NML), Brazil. In the case of beta radiation, the LMRI standard set consisted of $^{90}\text{Sr} + ^{90}\text{Y}$, ^{137}Cs , ^{14}C and ^{36}Cl calibrated sources (diameter 90 mm).

Before taking the measurements for the present study, each source was checked in relation to its activity using a control system (Dias and Caldas 1992) for alpha and beta radioactive sources, developed at IPEN. It consists mainly of a plastic scintillator, a light pipe (Lucite) and a photomultiplier tube, connected to a timer-counter system.

3. Results

3.1. Short and medium term stabilities

An ^{241}Am (2305 s^{-1}) source was used for this study. All detectors were positioned in a reproducible manner in relation to the radioactive source and 10 consecutive measurements were taken for the short term stability test of the four radiation detectors.

For the medium term stability test daily consecutive measurement series were performed up to 10 days. The obtained results are shown in table 1.

3.2. Linearity

This test was carried out using several ^{241}Am sources, with emission rates varying between 55.3 and $11\,100 \text{ s}^{-1}$. A linear behaviour was observed for the proportional counter and the scintillator up to 500 and $11\,100 \text{ s}^{-1}$ respectively, as can be seen in figures 1 and 2. The Geiger-Müller (GM) detector response is presented in figure 3, where linearity is observed up to 2500 s^{-1} , after which occurred the typical loss of efficiency for GM detectors in the 10^5 cpm range. In the case of the GM detectors, the response to ^{241}Am (2305 s^{-1}) was also taken for different irradiation time intervals (up to 5 min) and linearity was obtained.

3.3. Energy dependence

Alpha radiation sources with different energies were utilised in order to study the energy dependence of the contamination monitors. The

Table 1. Short and medium term stabilities of radiation detectors, source: ^{241}Am (2305.9 s^{-1}).

Probe	Short term stability variation coefficient (%)	Medium term stability variation coefficient (%)
HP 210AL	0.18	0.12
IEN 018	0.24	0.09
Proportional counter	2.06	0.41
Scintillator	1.08	0.28

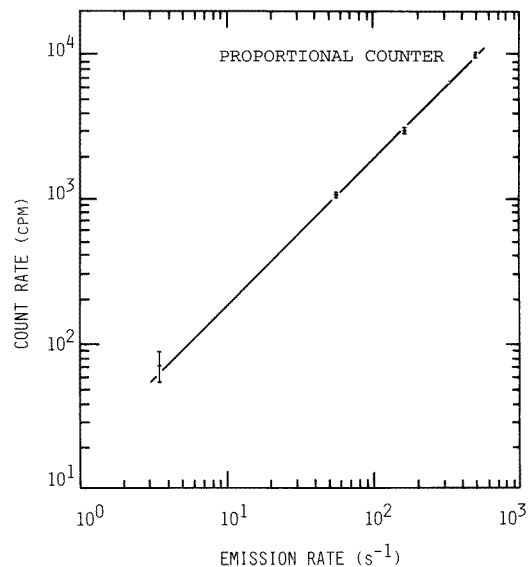


Figure 1. Proportional counter response to NML ^{241}Am sources with different emission rates.

correction factors for the energy dependence are presented for the GM detectors in table 2 and for the proportional counter and the scintillation systems in table 3. All four detectors were submitted to beta radiation, but only the GM detectors showed a significant variation in the correction factors for the different energies (table 4). It is important to note that the GM detectors are sensitive to gamma emissions, which may contribute to the detector response and consequently to its energy dependence.

3.4. Efficiency to alpha and beta radiation

The efficiency of the detectors was obtained using extended area reference sources of ^{241}Am

Table 2. Energy dependence of Geiger-Müller detectors for alpha radiation. F , correction factor for energy dependence normalised for ^{241}Am . Very low energy intensities were omitted.

Source	Alpha energy		Photon energy		F	
	(MeV)	(%)	(keV)	(%)	HP 210AL	IEN 018
^{233}U (171.8 s^{-1})	4.783	14.9	15.5	6.3	1.253 ± 0.021	1.188 ± 0.020
	4.824	82.7				
^{239}Pu (165.3 s^{-1})	5.105	11.7	16.4	5.8	1.168 ± 0.020	1.135 ± 0.019
	5.143	15.1				
	5.156	73.0				
^{238}Pu (183.5 s^{-1})	5.456	28.8	16.4	12.0	1.046 ± 0.018	1.049 ± 0.027
	5.499	71.0				
^{241}Am (167.2 s^{-1})	5.443	12.8	13.9	12.5	1	1
	5.486	85.2	17.8	18.0		
				59.5		
^{244}Cm (142.1 s^{-1})	5.763	23.6	17.3	10.5	0.970 ± 0.016	0.997 ± 0.018
	5.805	76.4				

Table 3. Energy dependence of the proportional counter and the scintillator systems for alpha radiation. F , correction factor for energy dependence normalised for ^{241}Am . These detectors are not sensitive to gamma radiation. Very low energy intensities were omitted.

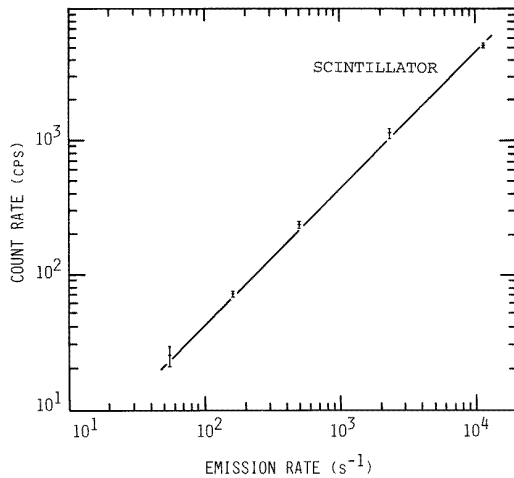
Source	Alpha energy		F	
	(MeV)	(%)	Proportional counter	Scintillator
^{233}U (171.8 s^{-1})	4.783	14.9	0.998 ± 0.024	1.029 ± 0.042
	4.824	82.7		
^{239}Pu (165.3 s^{-1})	5.105	11.7	1.032 ± 0.029	1.034 ± 0.039
	5.143	15.1		
	5.156	73.0		
^{238}Pu (183.5 s^{-1})	5.456	28.8	1.046 ± 0.025	0.986 ± 0.031
	5.499	71.0		
^{241}Am (167.2 s^{-1})	5.443	12.8	1	1
	5.486	85.2		
^{244}Cm (142.1 s^{-1})	5.763	23.6	1.049 ± 0.036	0.916 ± 0.035
	5.805	76.4		

Table 4. Energy dependence of Geiger-Müller detectors for beta radiation. F , correction factor for energy dependence normalised for $^{90}\text{Sr} + ^{90}\text{Y}$. Very low energy intensities were omitted.

Source	Beta energy		F	
	(keV)	(%)	HP 210AL	IEN 018
^{14}C (2946 s^{-1})	156.6	100.0	3.497 ± 0.193	4.161 ± 0.231
^{137}Cs (3465 s^{-1})	511.5	94.6	1.126 ± 0.020	1.511 ± 0.084
	1173.0	5.4		
^{36}Cl (3092 s^{-1})	709.5	98.1	0.995 ± 0.055	1.263 ± 0.070
$^{90}\text{Sr} + ^{90}\text{Y}$ (2930 s^{-1})	523.0	100.0	1	1
	2284.0	100.0		

Table 5. Efficiency of the contamination detectors for alpha radiation: extended area reference source of ^{241}Am (1631 s^{-1}).

Source–detector distance (cm)	Efficiency (%)			
	HP 210AL	IEN 018	Proportional counter	Scintillator
0.5	29.5	23.0	32.0	36.3
1.0	21.0	16.2	27.0	30.8
1.5	10.0	11.4	22.9	23.9

**Figure 2.** Scintillation detector response to NML ^{241}Am sources with different emission rates.**Table 6.** Efficiency of the contamination detectors (GM) for beta radiation: extended area reference source of $^{90}\text{Sr} + ^{90}\text{Y}$ (2930 s^{-1}).

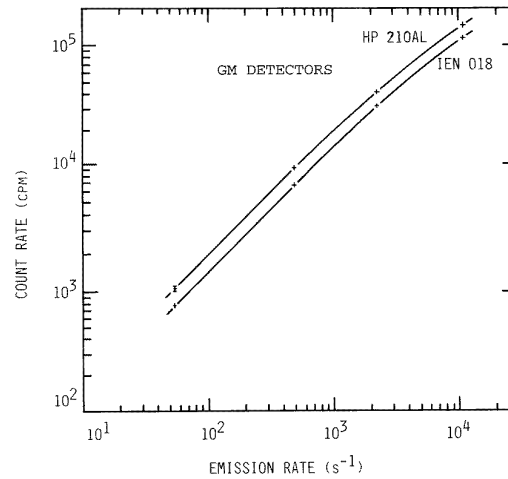
Source–detector distance (cm)	Efficiency (%)	
	HP 210AL	IEN 018
0.5	48.3	49.5
1.0	47.8	49.2
1.5	47.6	48.8

(diameter 197 mm) and $^{90}\text{Sr} + ^{90}\text{Y}$ (diameter 90 mm). Each instrument was positioned with its detector window at 0.5, 1.0 and 1.5 cm above the source surface.

The instrument efficiency (%) was determined by the following relation (ISO 1988a):

$$E_i = 100(n - n_b)(E_{se}A)^{-1}$$

where E_i is the instrument efficiency, the ratio

**Figure 3.** Geiger-Müller detectors response to NML ^{241}Am sources with different emission rates.

between the instrument net reading and the surface emission rate of a source under given geometrical conditions; n is the measured total count rate (s^{-1}); n_b is the background count rate (s^{-1}); A is the sensitive window area of the measuring instrument (cm^2); and E_{se} is the surface emission rate per unit area of the reference source ($\text{s}^{-1} \text{ cm}^{-2}$).

The results are presented in tables 5 and 6 for alpha and beta radiations respectively.

4. Conclusions

Four instruments commonly used for surface contamination measurements have been examined; all of them presented satisfactory short and medium term stabilities. Only the proportional counter showed mean standard deviation values higher than 1.1%. Response linearity was observed for all four cases (figures 1, 2 and 3).

The proportional counter exhibited only 5.1% energy dependence for alpha radiation in the studied energy range. In the case of beta radiation only the GM detectors presented measurement possibilities, with a very large energy dependence.

The efficiency for all four contamination monitors was determined for ^{241}Am radiation; as expected, it depends very strongly on the source–detector distance. It can be seen that the scintillator presented the highest efficiency. In the case of GM detectors the efficiency could be established also for beta radiation. At the 0.5 cm source–detector distance, the GM detectors showed almost a 50% efficiency for $^{90}\text{Sr} + ^{90}\text{Y}$ radiation.

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