CALIBRATION OF A PHOSWICH SYSTEM FOR THE IN VIVO MEASUREMENT OF 239-Pu AND 241-Am ACTIVITIES

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INTRODUCTION

The radiotoxicity of transuranic elements, particularly that of 239-Pu and 241-Am, has led to the development of a measuring system allowing for assessing low levels of lung inhalation by workers at the various restricted areas using these nuclides.

Estimations based on radiochemical analyses of excreta require the use of models whose transfer parameters, at a human level, are hard to assess.

Thus, direct measurement allows for insuring, both quickly and in a precise manner, the evaluation of a given internal contamination, as well as for avoiding the use of inaccurate metabolic parameters.

The use of phoswich detectors, with pulse shape discrimination (PSD), has led to attaining appropriate detection levels as per the regulations presently in force. Therefore, these systems have been preferently considered when dealing with the elements available for the control of internal contamination with 239-Pu and 241-Am.

MEASURING SYSTEM

The system utilized is composed by two phoswich detectors [3 mm NaI(Tl) and 50 mm CsI(Tl)], 127 mm in diameter, and by an electronic chain associated with each one of them.

The preamplifier is of the charge-sensitive type and has a special output that inhibits the system after a signal exceeding its dynamic rate. The PSD operation is based on the use of the crossover-crossover technique applied on a signal produced by two amplifiers with double delay lines and different delay times (1), (2), (3).

The system was implemented in such a way that the spectra of low-energy NaI(Tl) and high-energy CsI(Tl) crystals may be simultaneously stored, for each detector, at different positions in the multichannel analyzer core memory.(6)

The system is completed with a 6 m^3 monitoring room, shielded by a 15 cm iron wall. The inner side of the hall is shielded with 3 mm lead and 0.3 mm cadmium in order to improve the background of the low-energy area, plus a ventilation system with an absolute filter at the air inlet.

The detectors were compared individually with a NaI(Tl) crystal, with a multiwire proportional counter (4) and with the same counter plus an associate PSD. In the latter case, the constant fraction method was applied on the decay time of the signal produced by an amplifier with simple delay line.

The results in Table 1 show the advantages of using phoswich detectors in this type of measurements.

Table 1

	Efficiency $\left[\frac{cpm}{X \text{ or } \gamma\ min^{-1}}\right]$		Background (cpm)	
Detector	239-Pu	241-Am	239-Pu	241-Am
Phoswich 1	8.8 10^{-2}	8.9 10^{-2}	2.4	3.5
Phoswich 2	8.6 10^{-2}	8.7 10^{-2}	2.8	3.1
INa (Tl)	11.1 10^{-2}	8.9 10^{-2}	157.5	12.1
Proportional Counter	8.9 10^{-2}	3.4 10^{-3}	16.2	4.0
Proportional Counter + PSD	7.5 10^{-2}	2.4 10^{-3}	7.2	1.0

CALIBRATION METHODOLOGY

Assessment of the Calibration Factors

239-Pu produces 13, 17 and 20 Kev photons in a 4.6 10^{-2} proportion for each desintegration (uranium x rays). Besides, since the mean thickness of the soft tissue for 17 Kev is 6 mm and transmission at the skeleton is approximately 50%, only 1.6% of the x rays produced may be detected, for an individual with 3 cm chest soft tissue.

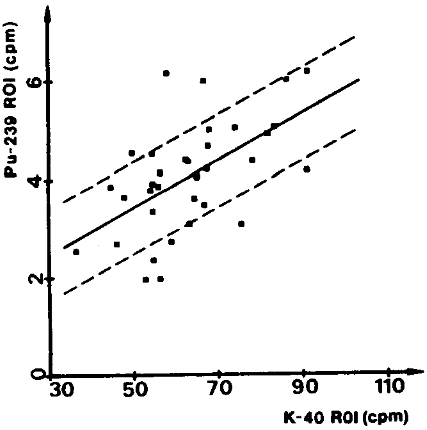
The measurement of known mixtures of 239-Pu and 241-Am is simpler, since the 60 Kev photons produced by 241-Am, with 36% efficiency by desintegration, are more easily detectable (mean thickness in soft tissue: 3.5 cm).

In order to assess the calibration, lungs of equivalent tissue were made with sources of 239-Pu and 241-Am uniformly distributed. These were adapted to a Remab hybrid phantom containing a human skeleton, with chest soft tissue approximately 3 cm thick (7),(8),(9).

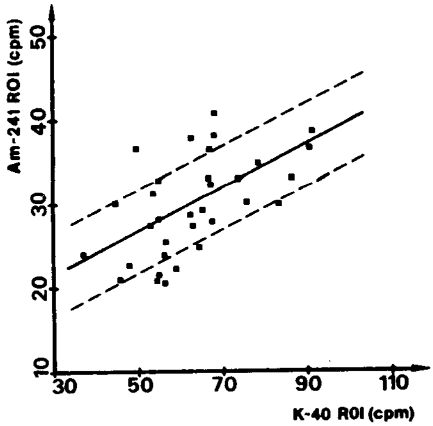
Prediction of the background

The presence of high-energy gamma-emitting nuclides, such as 40-K, produces background alterations in the various areas of interest (Roi's). For instance, for an individual with a mean amount of this nuclide, the background in the ROI for 239-Pu increases from 5.3 to 10.7 cpm and that in the ROI for 241-Am increases from 6.6 to 40.1 cpm.

Due to the above, the need arises to assess the background for each individual. Thus, a correlation was made between the 40-K content and the background variations at the ROIs for 239-Pu and for 241-Am, based on background measurements obtained from several persons (Graphs 1 and 2).



Graph 1



Graph 2

Corrections for Variations in the Thickness of the Soft Tissue

The calibration factors must be corrected in order to make them fit the anatomic features of each individual, since they were calculated for a soft tissue thickness that is usually different (Remab phantom).

In order to evaluate such difference, the methodology adopted was based on the measurement of the transmission resulting from placing a 600 $cm^2 \cdot$241-Am source under each individual's trunk (5).

These measurements, as well as a similar one performed on the above phantom, were related with a given thickness of equivalent tissue by means of experimental curves.

The coefficient utilized for correcting the calibration factor is that corresponding with one half the difference existing between the phantom and the individual and is also obtained by means of curves that were calculated by adding the phantom various thicknesses of equivalent tissue.

RESULTS

In order to evaluate the reliability of the method introduced herewith, a Remab phantom and a lung with 239-Pu and 241-Am uniformly distributed (Pu/Am = 54.7) were used, while the thickness of the chest equivalent tissue was increased in 1 cm.

Under these conditions, a series of measurements was performed and the activity of 241-Am was calculated with a maximum 12% error. For the direct evaluation of 239-Pu, the maximum error was 27%.

In this case, the minimum detectable activities (MDA) (10) were 52 nCi for 239-Pu and 0.12 nCI for 241-Am, while the ones for the reference phantom were 21 and 0.08 nCi respectively. The former were calculated with the calibration factors derived from the transmission resulting from the extense source and errors were 22 and 12% for 239-Pu and 241-Am respectively.

The MDA value obtained for the direct measurement of 239-Pu is high if compared with 16 nCi, which is the maximum allowed burden. However, if the calculation is made by using the Pu/Am ratio, that value results to be 7 nCi.

The importance of the errors made in the calculation of the activity, when the background is ignored because of variations in the 40-K content, is demonstrated by the calculation of the MDA. For an individual with an average 40-K content and a thickness of the soft tissue equal to that of the phantom, errors of 7% for 239-Pu and of 8% for 241-Am were found, the MDAs being 25 and 0.12 nCi respectively.

CONCLUSIONS

The figures shown above indicate that, although the detection levels for 239-Pu are generally higher than the lung burden derived from the recommended limits, their indirect measurement by means of 241-Am, plus the accuracy, versatility and fast applicability of the measuring method introduced herewith, make it particularly adequate for the routine control of professionally exposed workers, as well as for emergencies.

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