COMPARATIVE EVALUATION OF INCORPORATED ACTIVITY BY FOUR DIFFERENT WHOLE BODY COUNTERS

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INTRODUCTION

The assessment of internal radiation exposure requires the determination of the activity of incorporated radioactive substances and the knowledge of their biokinetic behaviour. If possible, the total body activity should be determined by direct measurements applying whole body or partial body counting. Thereby, serious problems can arise from differences in body size and shape, as well as from variations in the distribution of radioactivity within the subject. To overcome these problems, careful calibration of whole body counters is necessary. Long-term reproducibility of the calibration may be achieved by regular measurements of phantoms or activity sources in standard position. The accuracy of determinations of activity can only be realized by intercomparisons with the results obtained with other such devices. Several intercomparisons among whole body counters (1-4) showed that improper calibration may result in errors of estimated body activities of up to a factor of two or even more. With respect to the variations in the fall out of fission products from the Chernobyl accident, consistency of total body measurements throughout Europe for the estimation of the consequences due to ingestion of radioisotopes is required. The present study was aimed to compare the results obtained by four different whole body counters in Budapest/Hungary, Seibersdorf/Austria, and Frankfurt/Germany.

INSTRUMENTS

The whole body counter of the Central Research Institute for Physics, Budapest, is housed in a steel chamber with inner lead and copper lining. The routinely applied measuring arrangement is a modified single detector (6" x 4" NaI(Tl)-crystal) scanning-end-stop geometry with a scan length of 126 cm (5). The measured spectra are transferred to a PDP 11/34 computer and evaluated by least square fitting procedure using a preselectable set of calibration spectra stored in the spectrum library. For calibration, a BOMAB type standard phantom was used assuming uniform activity distribution. The measuring time applied for the persons of this intercomparison was 1294 seconds. The expected overall uncertainty for the determinations of the whole body activities of ^{134}Cs, ^{137}Cs, and ^{40}K is estimated as less than 11%.

The whole body counter operated by the Ges. für Strahlen- und Umweltforschung, Inst. für Biophysikalische Strahlenforschung, Frankfurt am Main, is housed in a basement with concrete walls of 2 metres thickness. The device is installed in a steel chamber (16 cm wall thickness). It applies the tilted chair geometry with a single 8" x 4" NaI(Tl)-detector, equipped with four 3"-photomultipliers. Gamma ray spectra are collected on a 0.5 K multichannel analyzer (5). Calibration of the counter for the measurement of ^{134}Cs, ^{137}Cs, and ^{40}K was performed using plastic bottles of 1 l and 2 l volumes, by which different body weights (between 10 kg and 100 kg) as well as different body shapes could be simulated. For this study, the subjects were measured for 20 minutes. The expected overall uncertainty for the determination of total body activities of ^{134}Cs, ^{137}Cs, and ^{40}K was estimated to be less than 10%.

The body counter at the Austrian Research Center Seibersdorf, Institute for Radiation Protection, employs a shadow shield tilted chair geometry. The outer shield consists of low activity 30 cm thick concrete walls lined by 1 cm steelplates. 4 NaI(Tl)-detectors are used. The backside of the chair is shielded by 5 cm of lead with copper lining and two detectors are integrated in the backside. The other two detectors mounted in front of the subject are also shielded with lead of 2-4cm thickness with copper lining. Thus, minimum detectable activities (3σ of background and 100% yield) for 1000 s measuring time are in the order of 100 Bq. Calibration of the counter was performed with a selfmade bottle-phantom (PTB-standard-solution with 7 radionuclides) by which different body weights and sizes could be simulated. Additionally, a high purity Germanium detector of 30% relative counting efficiency is installed in the same device for measurements with high energy resolution. The measured spectra are transferred to a PDP 11/34 computer and evaluated by a modified SAMPO-80 programme. The expected uncertainty for Caesium and Potassium is estimated as less than 10% (without statistical error).

The whole body counter at the laboratories of the International Atomic Energy Agency, Forschungszentrum Seibersdorf, is housed in a 249x188x233 cm (lengthxwidthxheight) steel chamber. The shielding is composed of 19 cm mill steel and 3 mm virgin lead. Also various counting methods and geometries are available. Only the tilting chair geometry is used for routine measurements. The measuring arrangement consists of a single 8" x 4" NaI(Tl)-detector with 3 photomultipliers, 1 K multichannel analyzer (Canberra S 35 plus), and for controlling and calculation a commodore 4032 computer. The measuring time for gamma ray counting is 600 seconds. The expected uncertainty without statistical error for the determinations of the whole body activities of ^{137}Cs and ^{40}K is estimated as less than 6%. The detection limit for ^{137}Cs is about 40 Bq.

SUBJECTS

The intercomparison measurements were performed on 8 healthy adult subjects (3 females, 5 males). Their body weights ranged

from 55 kg to 94 kg. Since the activities of the cesium isotopes varied slightly during the investigation period in spring 1987, all measurements for a particular person were carried out within one week. Only one subject (S.F.) underwent two courses of measurements, the first of which comparing the results as determined in Seibersdorf with those of Budapest and the second comparing Seibersdorf with Frankfurt. Subjects were measured at their home whole body counters immediately before and after the visit to all the other laboratories and the means of these two measurements were used as reference values.

Table 1: Total body activities of ^{134}Cs, ^{137}Cs, and ^{40}K as measured with the whole body counters in Budapest (KFKI), Seibersdorf (FZS and IAEA), and Frankfurt (GSF) in 8 healthy adult subjects.

Subject	Nuclide	Budapest KFKI (Bq)	Seibersdorf FZS (Bq)	Seibersdorf IAEA (Bq)	Frankfurt GSF (Bq)
H.Ch.	^{137}Cs	480	600	442	547
f, 55kg	^{134}Cs	187	280	-	204
	^{40}K	3224	3036	2817	3020
R.P	^{137}Cs	734	740	887	762
m, 93kg	^{134}Cs	286	310	-	304
	^{40}K	6385	4883	6291	5930
R.V.	^{137}Cs	466	520	479	503
f, 63kg	^{134}Cs	182	260	-	178
	^{40}K	4038	2441	2911	3285
W.E.	^{137}Cs	1005	1070	1096	1073
m, 84kg	^{134}Cs	392	490	-	420
	^{40}K	5321	4100	5603	5005
A.A.	^{137}Cs	1849	1830	1626	1786
m, 71kg	^{134}Cs	660	723	-	591
	^{40}K	4538	4539	3913	4223
B.E.	^{137}Cs	852	740	712	866
f, 68kg	^{134}Cs	305	286	-	259
	^{40}K	3318	2817	2661	3051
F.I.	^{137}Cs	1186	930	1177	1182
m, 94kg	^{134}Cs	424	374	-	375
	^{40}K	4570	4696	5133	4132
S.F.	^{137}Cs	3432	3310	3646	
m, 80kg	^{134}Cs	1338	1290	-	
	^{40}K	4132	3787	5133	
	^{137}Cs		3800	3752	3742
	^{134}Cs		1540	-	1276
	^{40}K		3975	4194	3963

RESULTS

The data obtained from the four whole body monitor laboratories are summarized in table 1. Since the calibration for ^{134}Cs had not been completed for the instrument operated by the IAEA, no body activities of that radionuclide could be evaluated for this place. In general, the results obtained show a good agreement. For the radionuclide ^{137}Cs, there are no systematic deviations between any two of the four laboratories. Although particular measurements even on the same day show differences of activity determination of up to about 25%, the sums of ^{137}Cs-activities of all measurements coincide within 5%. Since in the calculation of ^{137}Cs body activity the ^{134}Cs contribution in the photopeak region of ^{137}Cs has to be considered but not vice versa, even better agreement could be expected for the evaluation of ^{134}Cs activities. Actually, the observed deviations are greater for ^{134}Cs than for ^{137}Cs. This may be due to the poorer statistics and the different evaluation methods applied. Similar differences of up to 15% are also seen for the mean values of potassium (^{40}K).

CONCLUSIONS

The mean values of all three isotopes show no systematic deviations between the four laboratories, whereas for a particular person the differences may exceed those that could be expected from counting statistics. This intercomparison again demonstrates that in whole body counting systematic errors in reproducibility of subject and detector positioning together with the evaluation technique applied are predominating. During the preceeding years separate comparative measurements have been carried out in Eastern Europe including Budapest (4) as well as in Western Europe including Frankfurt and Seibersdorf (1,3). The data presented here close the gap between both parts of Europe, showing that there are no systematic deviations in the assessment of total body activity by direct measurements applying whole body counting.

LITERATURE

1) H. Schmier: Kalibrierungsvergleich von Ganzkörperstrahlungsmeßanlagen in den Ländern der Europäischen Gemeinschaft. Bericht EUR 4762 d (Euratom Vertrag Nr. 041-68-7 PSTD), Luxemburg, 1972
2) H.W. Julius, C.W. Verhoef in: EG Progress Report Programme "Radiation Protection 1979", 6766 DA/DE/ENFR/IT/NL, S. 143-146
3) R. Kunkel, E. Werner, H. Schmier: Intercomparison Measurements on Thirty Whole Body Counters. IVth European Congress / XIIIth Congress of IRPA, Salzburg, 15.-19.9.86, in press
4) A. Andrasi, E. Beleznay: International Intercomparison of Whole Body Counters. Report KFKI-1979-95 (ISBN 963 371 622 5)
5) Directory of Whole-Body Radioactivity Monitors. IAEA, Vienna 1970
6) R. Kunkel, A. Böhne, H. Doerfel, P. Koeppe, E. Rose, H. Schieferdecker, E. Werner: Inkorporationsüberwachung durch Direktmessung der Körperaktivität. Loseblattsammlung, Fachverband für Strahlenschutz, FS-80-24-AKI, Würenlingen 1980