Calibration of Hand-held Instruments for Whole Body Measurements of Caesium-137

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ABSTRACT

The responses of eight hand-held instruments to ^{137}Cs internal contamination in people are determined. The caesium was presented in the form of a bottle manikin absorption (BOMAB) phantom filled with ^{137}Cs in solution. The phantom was assembled to represent the ICRP 23 Reference Man and five smaller configurations representing a 16, 14, 8, and 4 year old, and a 3 month old infant. Measurements were taken at 30 cm, 1 m, and 2 m above the surface of the part/s representing the chest with the phantom arranged horizontally. This corresponds to positioning the instrument at the abdominal end of the sternum in a human subject.

Minimum detectable activity (MDA) values were calculated for whole body and lung measurements. The MDAs for whole body measurement of an adult at 30 cm ranged from 140 kBq to 2 MBq, but were ≈ 10 kBq for the three instruments with a region of interest (ROI) set up for the ^{137}Cs photopeak. Generally, MDAs decreased with decreasing age/size, with those for the 3 month old infant at about 55% of those for the adult. For lung measurements at 30 cm MDA values were about 70% of those for whole body. MDAs at 1 m were about 5x higher than at 30 cm, and at 2 m about 15x higher.

Committed effective doses corresponding to the MDA values, 24 hours after intake of soluble ^{137}Cs, ranged from 2 to 30 mSv for an adult measured at 30 cm, or about 0.15 mSv when ROI facilities were used. Corresponding doses to children, 16 to 4 years of age, decreased with decreasing age, but those for the 3 month old infant were similar to those for the adult.

Many of the instruments tested were readily capable of detecting ^{137}Cs activities in whole body, which correspond to a committed effective dose of 10 mSv, for intake by inhalation, 24 hours before measurement.

The procedures and instruments described in this report could be used to rapidly monitor a large group of people for ^{137}Cs internal contamination. The results of this screening could be used to identify people for possible decorporation therapy.

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EXECUTIVE SUMMARY

The responses of eight hand-held instruments to ^{137}Cs internal contamination in people were determined.

The caesium was presented in the form of a bottle manikin absorption (BOMAB) phantom filled with ^{137}Cs in solution. The phantom was assembled to represent the ICRP 23 Reference Man and five smaller configurations representing a 16, 14, 8, and 4 year old, and a 3 month old infant. Phantom activities ranged from approximately 1300 kBq in the adult to 100 kBq in the 3 month old. Measurements of whole body and lung, where the chest section/s only were filled with caesium solution, were taken at 30 cm, 1 m, and 2 m above the surface of the part/s representing the chest with the phantom arranged horizontally. This corresponds to positioning the instrument at the abdominal end of the sternum in a human subject.

Statistically significant responses were obtained from seven of the eight instruments for whole body and lung measurements, on all ages represented, at 30 cm; from six instruments at 1 m; and six instruments, for at least the adult configuration, at 2 m.

Minimum detectable activity (MDA) values for each instrument providing a statistically significant response were calculated. The MDAs for whole body measurement of an adult at 30 cm ranged between 140 kBq and 2200 kBq, but were about 10 kBq for the three instruments with a region of interest (ROI) set up for the ^{137}Cs photopeak.

MDAs for whole body measurements of phantoms representing children, at 30 cm, generally decreased with decreasing size, but there was less dependence on size with the detector at greater distances. Thus the MDA for a 3 month old infant was about 55% of the value for the adult at 30 cm, and 70% at 1 m.

For lung measurements at 30 cm MDA values were about 70% of those for whole body. These values rise to about 90% at 1 m.

For instruments from which statistically significant responses were obtained, MDAs at 1 m were about 5x higher than at 30 cm, and at 2 m were about 15x higher.

Committed effective doses were calculated to correspond to the whole body MDA values, 24 hours after intake (by inhalation, injection, or ingestion) of ^{137}Cs in soluble form, giving a uniform whole body distribution of activity. These ranged from 2 to 30 mSv for an adult measured at 30 cm, or about 0.15 mSv when ROI facilities were used. Corresponding doses to children, 16 to 4 years of age, decreased with decreasing age, but those for the 3 month old infant were similar to those for the adult, due to the higher dose coefficient for this age.

Doses corresponding to the whole body MDA values, at 1 m and 2 m were about 5x and 15x higher than at 30 cm, respectively.

The results of these tests show that the best instrument sensitivity is displayed at a monitoring distance of 30 cm. The suitability of the instruments, however, depends upon the selected intervention level (the level at which follow-up measurements would be

required), the age range of the affected population, and the delay between intake and measurement.

In the event of a radiological incident involving the release of ^{137}Cs and requiring the rapid monitoring of large numbers of members of the public, five of the instruments tested would be suitable for measuring the activity due to a dose of 10 mSv, at a measurement distance of 30 cm, across the entire age range. At 1 m, four of the instruments would be suitable.

CONTENTS

1 INTRODUCTION

Several radioactive isotopes of caesium exist, the most significant, due to its widespread availability and use in industry and medicine, being caesium-137 (^{137}Cs), which emits beta and gamma radiation (radioactive half-life 30 years). Most caesium compounds are soluble and are readily absorbed from the gastrointestinal (GI) tract, lungs and wounds. They behave similarly to potassium in the body and therefore internal contamination with radioactive caesium causes whole body irradiation. Caesium-137 has a two component biological half-life, 2 d for 10% and 110 days for 90%: 80% is excreted through the kidneys and 20% in faeces (ICRP, 1997).

The rate of removal of some radionuclides from the body can be increased by the administration of drugs: a procedure known as decorporation therapy. The compound iron III ferrocyanide, commonly referred to as Prussian Blue, increases excretion of ^{137}Cs and can significantly reduce the committed effective dose. Prussian Blue is not absorbed through the intact GI wall after ingestion, so its clearance from the body depends on the GI tract transit time. It binds caesium isotopes in the GI tract after they are ingested, or excreted in the bile by the liver, thereby reducing GI reabsorption. Insoluble Prussian Blue acts by ion-exchange, adsorption, and mechanical trapping within the crystal structure and has a very high affinity for caesium.

Prussian Blue is most effective when administered within 24 hours after the ingestion or inhalation of radioactive caesium, but therapy is still effective when begun days after exposure. It is a safe and effective drug, however a prolonged course of daily treatment over a number of months may be required to reduce the dose by a factor of 2-3 (Melo et al, 1994; Stradling et al, 2000).

A rapid survey of people, using hand-held instruments, may be useful to detect internal contamination following an incident where ^{137}Cs has been released. They are likely to be much less sensitive than purpose built equipment (whole body monitors) but could be rapidly deployed to screen large numbers of people. Ideally, measures would be taken to ensure that external contamination is removed before measurements are made to prevent this being interpreted as internal contamination, and to help prevent the spread of contamination. However, depending on the scale of the incident, it might be appropriate to monitor people even with external contamination, if activities, and hence doses, are low many people could be screened quickly and reassured.

This study aimed to determine the responses of a selection of hand-held instruments to ^{137}Cs in people. Minimum detectable activity (MDA) values for each instrument were calculated and also the approximate doses to which these would correspond, as measured 24 hours after intake. The MDA values were used to determine if the instruments tested are sensitive enough to be used to identify levels of ^{137}Cs in people where decorporation therapy could be considered.

2 EXPERIMENTAL

Eight hand-held contamination instruments were tested for their response to ^{137}Cs in whole body and also in lungs only. The whole body distribution of caesium is the most likely for soluble compounds via any intake route. The lung only distribution represents contamination by an insoluble, or moderately soluble, caesium compound after inhalation: the most likely route of intake early after an incident.

The instruments were selected due to their suitability for the purpose: having a relatively large NaI crystal; or being readily available (42B and 44A probes are used in most medical physics laboratories, and the RAM GENE-1 is widely used in hospitals). All measurements took place between 29th November and 18th December 2006. The caesium was presented in the form of a bottle manikin absorption (BOMAB) phantom (Health Physics Society, 1999) filled with a solution of ^{137}Cs, stable CsCl carrier and dilute hydrochloric acid. The phantom consists of 10 high-density polyethylene containers that assemble to represent the ICRP 23 Reference Man human body (170 cm, approx. 60 litres) (ICRP, 1975). Five smaller configurations of the phantom were also measured, representing a 16, 14, 8, and 4 year old, and a 3 month old infant (Youngman, 2002).

Measurements of radioactive caesium in people would normally be made with the person standing, therefore calibrations should be made with the BOMAB in an upright position. However, BOMAB phantoms are designed to be used supine, supporting them in an upright position causes them to be more prone to leaks. Therefore it was decided to place the BOMAB on the floor to make the measurements. However, under these circumstances the high mass of material under the BOMAB could produce some back-scatter of radiation and increase the measured count rate (cps). The magnitude of this effect was determined by measuring the count rate with the phantom placed on the floor and then on a table (low mass of material under the phantom). The percentage difference between the count rate recorded on the floor and on the table was calculated [Section A1 *Back-scatter: method and results*].

The differences observed can be reasonably attributed to natural variation in background radiation. It was decided that the practical advantages of lying the phantom down outweighed any possible bias created by the difference in count rate.

2.1 Background measurements

Each instrument was used to measure the count rate for a distilled water-filled BOMAB phantom, in each of the age configurations, to provide background measurements [Section A2.1 *Distilled water phantom background*]. The positioning of the instruments relative to the phantom was the same as for the calibration measurements [Section 2.2 *Calibration measurements*].

Additionally, a human volunteer was measured using each of the instruments to determine whether naturally-occurring ^{40}K would contribute significantly to the count rate. Results fell well within the range of the measurements taken with the distilled water

phantom in place, and it was therefore assumed that the distilled water phantom gave a count rate which was a good representation of the background from a human subject [Section A2.2 *Person background*].

2.2 Calibration measurements

Each instrument was used to carry out measurements of the BOMAB phantom in each of the configurations listed below, representing six different ages. Phantom activities were in the range 100 kBq for a 3 month old infant to 1300 kBq for an adult (Table 1). The activity is distributed in proportion to the volume of each phantom part.

Table 1 BOMAB phantom configurations to represent different ages

Age represented	Parts in configuration	Approx. total activity (kBq)
Standard adult	Head	Whole body: 1283
	Neck	Chest (lung): 364
	Chest + 2 Arms	
	Pelvis	
	2 Thighs	
	2 Shins	
16 yr old	Head	Whole body: 1144
	Neck	Chest (lung): 364
	Chest + 2 Arms	
	Pelvis	
	2 Shins	
	Thigh	
14 yr old	Head	Whole body: 879
	Neck	Chest (lung): 364
	Chest + 2 Arms	
	2 Shins	
	Shin	
8 yr old	Head	Whole body: 427
	Neck	Chest (lung): 181
	2 Shins	
	2 Arms	
4 yr old	Head	Whole body: 302
	Thigh	Chest (lung): 137
	Shin	
3 month old	Neck	Whole body: 111
	Shin	Chest (lung): 88

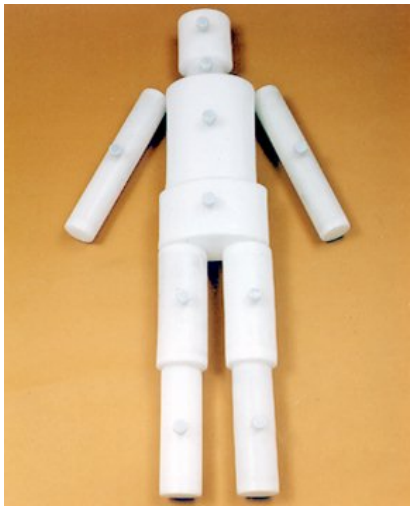

Fig. 1. Arrangement of the bottle manikin absorption (BOMAB) phantom: Standard adult

2.2.1 Measurement protocol

The ^{137}Cs BOMAB phantom was arranged on the floor in each of the configurations, in turn.

Measurements were taken using each instrument at 30 cm, 1 m, and 2 m above the surface of the part/s representing the chest. Since the filling cap was in the centre of most 'chests', instruments were positioned 10 cm below the centre of the filling cap, i.e. towards the feet. This position corresponds to positioning the instrument at the abdominal end of the sternum in a human subject.

For those instruments that have end caps, the measurements were taken with the end caps on.

Similar measurements were taken using ^{137}Cs 'chest' parts with distilled water parts making up the remainder of the phantom. This was done to represent contamination in the lungs only.

Two measurements were taken in each combination.

2.2.2 Instrument settings

The InSpector and identiFINDER are capable of attachment to a computer and are supplied with software allowing more functions and options than available on the stand-alone device. This capability was not used in this study as it was decided that in an emergency there might not be time or facility to use it, and it is likely that the instruments would be used 'off the shelf'.

The 44A, 42B and MC-71 probes were used with a digital scaler to obtain total counts in a set time period. These instruments are more usually connected to analogue scale ratemeters, under which circumstances a positive measurement of ^{137}Cs is indicated by a count rate which is greater than or equal to twice the background count rate. This

would not affect the calibration factors, however, it would probably have the effect of raising the MDAs by a small amount.

2.2.2.1 Instruments with no spectrometry capability

The identiFINDER was set to count for 60 seconds. The count rate was calculated from the total count.

The Mini 6-90 digital scaler was set for a 60 second count time for the 44A and MC-71 probes and 100 seconds for the 42B probe. The count rate was calculated from the total counts.

The MC71 probe is sensitive not only through the end, but also along its length. Therefore, each set of measurements was carried out twice with this probe, with the end towards the phantom and with the probe held lengthways along the axis of the phantom.

The RAM GENE-1 provided an instantaneous count rate for the whole spectrum. The display was observed for 60 seconds. As the instrument only displayed zero, one, or two during all the measurements, a subjective judgement of the value displayed the most was taken as the count rate result. The RAM GENE-1, which has a 44.5 mm diameter pancake Geiger-Müller detector, was not expected to be particularly sensitive, however it was almost entirely unresponsive to the activity levels of the phantoms at a distance of 30 cm or greater. A reading of about 10 cps was achieved with the instrument held 1 cm above the chest of the ^{137}Cs phantom, i.e. as it would be used for surface-contamination monitoring.

2.2.2.2 Instruments with a spectrometer capability

In addition to a measurement of count rate across the entire energy range, for these instruments the counts in a ^{137}Cs region of interest (ROI) was also possible. This has the advantage of allowing more sensitive measurements to be made. The InSpector, GR-135 and GR-130 were each pre-set by the manufacturer with a region of interest for ^{137}Cs on the spectrum. Measurements were carried out of the instrument's response in this restricted energy range in addition to the full scale measurements.

The GR-130 and GR-135 were set to count for 60 seconds. The count rate was calculated from the total count for the whole spectrum and the ROI.

The InSpector provided an instantaneous count rate for the whole spectrum. The display was observed for 60 seconds and the mean of the lowest and highest counts was calculated. Separate measurements had to be made for the ROI as this was under a different function. The measurement time was set for 60 seconds and the count rate calculated from the total counts in the ROI.

3 RESULTS AND DISCUSSION

All raw background and calibration data is given in APPENDIX A.

Prior to use in further calculations measured calibration count rates were assessed with respect to statistical significance. Results equal to or lower than the critical limit (L_C) were deemed to be background counts and designated “Not Significant” (NS). Results equal to or lower than the detection limit (L_D) are considered to have a high degree of uncertainty but were used for further calculation and MDAs derived from them are shown in the following tables as values in brackets. Throughout this study, calculated values of L_C and L_D are for a level of certainty of 95%. Thus at the critical limit, there is a 95% certainty that the count was statistically significant, and if a count is equal to the detection limit there is a 95% certainty of detection (Gilmore and Hemingway, 1995).

The individual measurement results were used to calculate the efficiency of the detector response (cps/kBq) for each of the instruments evaluated; relating measured count rate to activity in whole body or lungs. All duplicate calculated results are shown in Section A4 *Detector Efficiency*, Tables A30 to A47.

3.1 Minimum Detectable Activities (MDAs)

The MDA in this report is the lowest activity which can be detected with 95% confidence. Individual MDAs were calculated from each measurement result and then the mean of the duplicate results was taken. As the calculated MDAs did not show a large variation with subject age, only MDAs for four ages are shown in Tables 2 to 7. In order not to underestimate the ^{137}Cs activity in children where a specific calibration factor is not given, it is recommended that the calibration factors for the next oldest age are used.

The MDA for a full scale measurement was calculated as:

$$2(\text{background}) / \text{counting efficiency}$$

and for an ROI measurement of the calculation was:

$$4.65\sqrt{(\text{background} \times \text{count time (s)})} / \text{count time (s)} \times \text{counting efficiency}$$

For some instruments, for 1 m and 2 m measurement distances, it was not possible to calculate MDA values using these formulae as the BOMAB phantom activity, used to determine the counting efficiency, was below the MDA for the instrument. In these cases, values were extrapolated from the results at 30 cm to the 1 m and 2 m measurement distances. The value of each significant result, e.g. at 2 m, was divided by the value of the corresponding measurement at 30 cm to provide a multiplication factor. The mean of the multiplication factors was found and used to extrapolate individual instrument results from 30 cm to values for the greater measurement distances.

Table 2 Minimum Detectable Activities for whole body measurement at 30 cm (kBq)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	430	370	330	(240)
	ROI	10	9	7	5
GR-135	Full scale	250	210	190	140
	ROI	14	11	9	5
GR-130	Full scale	220	190	170	130
	ROI	13	11	9	6
identiFINDER	Full scale	1100	930	(890)	(650)
MC71 end on	Full scale	(2200)	(2200)	(1900)	(1400)◊
MC71 lengthways	Full scale	(1300)	(1100)	(1000)	(620)
44A	Full scale	140	110	110	87
42B	Full scale	220	200	180	(140)
RAM GENE-1	Full scale	NS	NS	NS	NS

Note. 1. Values given to 2 significant figures.

2. ROI MDAs calculated for count time = 60 s.

3. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

4. ◊ Values derived from only one significant measurement.

5. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence. MDA is greater than the activity of the appropriate phantom (Table 1).

Table 3 Minimum Detectable Activities for whole body measurement at 1 m (kBq)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	1700	1600	(1700)	(1000)
	ROI	47	43	37	(31)
GR-135	Full scale	1000	940	(850)	(790)
	ROI	69	55	(46)	(52)
GR-130	Full scale	890	840	(800)	(730)
	ROI	57	53	(46)	(32)
identiFINDER	Full scale	(4500)	(4400)	(4300)	(4200)
MC71 end on	Full scale	(6900)	(5600)	(8900)*	(6600)*
MC71 lengthways	Full scale	(5800)	(4200)	(2600)◊	(1200)◊
44A	Full scale	540	530	(560)	(470)
42B	Full scale	830	(760)	(1000)	(830)◊
RAM GENE-1	Full scale	NS	NS	NS	NS

Note. 1. Values given to 2 significant figures.

2. ROI MDAs calculated for count time = 60 s.

3. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

4. ◊ Values derived from only one significant measurement.

5. *Values extrapolated from MDAs at 30 cm; using a mean multiplication factor derived from actual results at 30 cm and 1 m for each instrument.

6. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence. MDA is greater than the activity of the appropriate phantom (Table 1).

Table 4 Minimum Detectable Activities for whole body measurement at 2 m (kBq)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	(4700)	4800*	4300*	(3100)*
	ROI	120	110*	87*	59*
GR-135	Full scale	(2900)	(2600)	2400*	1700*
	ROI	(220)	(190)	110*	70*
GR-130	Full scale	(2500)	(2300)	(2000)	1700*
	ROI	(200)	(170)	(180)	81*
identiFINDER	Full scale	(12000)	(11000)	(8700)	(6300)
MC71 end on	Full scale	(12000)◊	(28000)*	(25000)*	(18000)*
MC71 lengthways	Full scale	(17000)*	(14000)*	(13000)*	(8000)*
44A	Full scale	(1600)	(1500)	(1700)	(1500)
42B	Full scale	(2300)	(2500)	2300*	(930)◊
RAM GENE-1	Full scale	NS	NM	NM	NM

Note. 1. Values given to 2 significant figures.

2. ROI MDAs calculated for count time = 60 s.

3. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

4. ◊ Values derived from only one significant measurement.

5. *Values extrapolated from MDAs at 30 cm; using a mean multiplication factor derived from actual results at 30 cm and 2 m for each instrument.

6. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence. MDA is greater than the activity of the appropriate phantom (Table 1).

7. NM = No measurement.

Table 5 Minimum Detectable Activities for lung measurement at 30 cm (kBq)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	270	270	260	(230)
	ROI	6	6	5	5
GR-135	Full scale	160	160	150	130
	ROI	8	9	7	5
GR-130	Full scale	140	140	130	130
	ROI	8	8	6	6
identiFINDER	Full scale	680	700	(650)	(620)
MC71 end on	Full scale	(2700)	(1700)	(1400)	(740)
MC71 lengthways	Full scale	(790)	(930)	(670)	(510)
44A	Full scale	75	79	80	85
42B	Full scale	120	110	(120)	(120)
RAM GENE-1	Full scale	NS	NS	NS	NS

Note. 1. Values given to 2 significant figures.

2. ROI MDAs calculated for count time = 60 s.

3. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

4. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence. MDA is greater than the activity of the appropriate phantom (Table 1).

Table 6 Minimum Detectable Activities for lung measurement at 1 m (kBq)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	(1500)	(1500)	(1400)	(1000)
	ROI	45	42	(35)	(32)
GR-135	Full scale	(830)	(870)	(830)	(800)
	ROI	(56)	(52)	(44)	(50)
GR-130	Full scale	(720)	(760)	(740)	(670)
	ROI	48	48	(47)	(37)
identiFINDER	Full scale	(4100)	(3800)	(3900)	(4900)
MC71 end on	Full scale	(3600)◊	(10000)*	(8400)*	(4400)*
MC71 lengthways	Full scale	(4000)	(5500)*	(4000)*	(3000)*
44A	Full scale	(460)	(490)	(530)	(480)
42B	Full scale	(620)	(650)	(570)	(520)
RAM GENE-1	Full scale	NS	NS	NS	NS

Note. 1. Values given to 2 significant figures.

2. ROI MDAs calculated for count time = 60 s.

3. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

4. ◊ Values derived from only one significant measurement.

5. *Values extrapolated from MDAs at 30 cm; using a mean multiplication factor derived from actual results at 30 cm and 1 m for each instrument.

6. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence. MDA is greater than the activity of the appropriate phantom (Table 1).

Table 7 Minimum Detectable Activities for lung measurement at 2 m (kBq)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	(2800)	4300*	4100*	(3700)*
	ROI	(68)	100*	83*	73*
GR-135	Full scale	(2500)	2500*	2400*	2000*
	ROI	(300)	140*	110*	86*
GR-130	Full scale	(2000)	2200*	2100*	2100*
	ROI	(190)	130*	100*	93*
identiFINDER	Full scale	(9600)	(9900)	(6400)	(4200)
MC71 end on	Full scale	(42000)*	(27000)*	(22000)*	(12000)*
MC71 lengthways	Full scale	(13000)*	(15000)*	(11000)*	(8100)*
44A	Full scale	(1300)	(1300)	1300*	1300*
42B	Full scale	(1800)	(1900)	(1900)*	(1900)*
RAM GENE-1	Full scale	NM	NM	NM	NM

Note. 1. Values given to 2 significant figures.

2. ROI MDAs calculated for count time = 60 s.

3. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

4. *Values extrapolated from MDAs at 30 cm; using a mean multiplication factor derived from actual results at 30 cm and 2 m for each instrument.

5. NM = No measurement.

The MDAs calculated from the whole body data are representative of a subject measurement where the radioactivity is distributed throughout the body. This will be the case in most caesium measurements, as clearance from the lungs to the blood is rapid for the majority of caesium compounds. These MDAs are higher than those from the lung measurements because the activity is distributed over a greater area and is therefore less readily detectable, due to distance from the probe and the directional sensitivity of the probes.

For lung measurements at 30 cm MDA values were about 70% of those for whole body. These values rise to about 90% at 1 m. The MDA values for the 3 month old infant are generally over 90% of the whole body MDAs at both measurement distances, but this is almost certainly due to the minimal difference between the lung and the whole body phantoms, for this age.

MDAs for whole body measurements at 30 cm generally decreased with decreasing size, but there was less dependence on size with the detector at greater distances. Thus the MDA for a 3 month old infant was about 55% of the value for the adult at 30 cm, and 70% at 1 m. However, the activity in the smaller phantoms is so much less than in the larger configurations that the measured count rate is less likely to be significantly above background.

For instruments from which responses were significantly above background, MDAs at 1 m were about 5x higher than at 30 cm, and at 2 m were about 15x higher.

The results highlight the unsuitability of the RAM GENE-1 and the MC-71 probe, particularly, for this type of measurement. The identiFINDER, though sensitive, had such a high background the calculated MDAs were high, compared to instruments based on similar detectors.

The sensitivity of the 44A and 42B probes to ^{137}Cs is not great, but with their low background counts, the calculated MDAs for these instruments are quite low, and compare favourably with those of the more sophisticated and expensive instruments. The main advantage of the latter is the availability of the ROI feature.

Using the ROI facility, where available, decreases the MDA significantly and is recommended where the identity of the radionuclide to be measured is known. The three instruments with this facility tested here also have radionuclide identification capability.

3.2 Doses corresponding to MDAs

The calculated MDAs have been related to the approximate committed effective dose to which this corresponds, when measured 24 hours after intake of ^{137}Cs in soluble form, giving a uniform whole body distribution of activity. As committed effective doses do not show a large variation with subject age, only those for four ages are shown in Tables 8 to 10. Where a specific value is not given, it is recommended that reference is made to the next oldest age, so the dose corresponding to the MDA is not underestimated.

Doses were calculated from the whole body measurement data using the computer program ERIDAS (Youngman et al, 2007), designed to calculate doses to different ages, using dose coefficients from ICRP Publication 72 (ICRP, 1996).

Table 8 Effective Dose corresponding to Minimum Detectable Activities for whole body measurement at 30 cm, 24 hours after intake (mSv)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	5	4	3	(5)
	ROI	0.12	0.11	0.06	0.10
GR-135	Full scale	3	3	2	3
	ROI	0.17	0.13	0.08	0.10
GR-130	Full scale	3	2	2	3
	ROI	0.16	0.13	0.08	0.12
identiFINDER	Full scale	13	11	(8)	(13)
MC71 end on	Full scale	(27)	(26)	(17)	(27)
MC71 lengthways	Full scale	(15)	(13)	(9)	(12)
44A	Full scale	2	1	1	2
42B	Full scale	3	2	2	(3)
RAM GENE-1	Full scale	NS	NS	NS	NS

Note. 1. Assuming Type F ^{137}Cs compound.

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

Table 9 Effective Dose corresponding to Minimum Detectable Activities for whole body measurement at 1 m, 24 hours after intake (mSv)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	20	19	(15)	(20)
	ROI	0.6	0.5	0.3	(0.6)
GR-135	Full scale	12	11	(8)	(15)
	ROI	0.8	0.7	(0.4)	(1.0)
GR-130	Full scale	11	10	(7)	(14)
	ROI	0.7	0.6	(0.4)	(0.6)
identiFINDER	Full scale	(53)	(53)	(38)	(80)
MC71 end on	Full scale	(83)	(67)	(79)*	(130)*
MC71 lengthways	Full scale	(69)	(50)	(23)	(23)
44A	Full scale	6	6	(5)	(9)
42B	Full scale	10	(9)	(9)	(16)
RAM GENE-1	Full scale	NS	NS	NS	NS

Note. 1. Assuming Type F ^{137}Cs compound.

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. *Values derived from extrapolated MDAs.

4. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

Table 10 Effective Dose corresponding to Minimum Detectable Activities for whole body measurement at 2 m, 24 hours after intake (mSv)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	(56)	58*	38*	(60)*
	ROI	1	1*	1*	1*
GR-135	Full scale	(34)	(31)	22*	34*
	ROI	(3)	(2)	1*	1*
GR-130	Full scale	(30)	(27)	(18)	33*
	ROI	(2)	(2)	(2)	2*
identiFINDER	Full scale	(150)	(130)	(77)	(120)
MC71 end on	Full scale	(150)	(340)*	(220)*	(350)*
MC71 lengthways	Full scale	(200)*	(160)*	(120)*	(150)*
44A	Full scale	(19)	(18)	(15)	(29)
42B	Full scale	(28)	(30)	21*	(18)
RAM GENE-1	Full scale	NS	NM	NM	NM

Note. 1. Assuming Type F ^{137}Cs compound.

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. *Values derived from extrapolated MDAs.

4. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

5. NM = No measurement.

The results show little difference in the committed effective dose corresponding to the MDAs across the age range for a particular instrument.

Doses ranged from 2 to 30 mSv for an adult measured at 30 cm, or about 0.15 mSv when ROI facilities were used. Corresponding doses to children, 16 to 4 years of age, decreased with decreasing age, but those for the 3 month old infant were similar to those for the adult, due to the higher dose coefficient for this age.

Doses corresponding to MDAs at 1 m and 2 m were about 5x and 15x higher than at 30 cm, respectively.

If, for illustrative purposes, a dose level of 10 mSv was set as the intervention level, then all the instruments except those with ROIs would be unsuitable for screening at a distance of 2 m. On the same basis, only the 44A and the instruments with ROI facility would be suitable at a distance of 1 m; the others not being capable of detecting activity corresponding to a dose lower than 10 mSv.

Doses corresponding to the MDAs from the lung measurement data were not calculated as it was predicted, using the computer program IMBA (**I**ntegrated **M**odules for **B**ioassay **A**nalysis) Professional Plus V.4.0 (Birchall et al, 2006), that following an inhalation of a type S caesium compound, 13.5% of inhaled activity would be present in the lungs between 0-1 h (12% after 24 h). Therefore even at very short times between intake and measurement, the whole body calibration factors should be used. For comparison, 0.2% of inhaled activity of a type F caesium compound would remain in the lungs of an adult 1 h after intake. If the inhaled caesium compound was type S it would be expected that

the effective doses corresponding to the MDAs given in Tables 8-10 would be increased by about a factor of 10-15.

In general, then, it is recommended that the instruments tested should be used for whole body measurements at a distance of 30 cm if the action level for screening is 10 mSv or less.

4 CONCLUSIONS

This study aimed to determine the responses of a selection of eight hand-held instruments to ^{137}Cs internal contamination in people. Whole body distribution of caesium is the most likely for soluble compounds via any intake route, however, measurements were also carried out of lung only distribution; representing contamination by an insoluble, or moderately soluble, caesium compound after inhalation: the most likely route of intake early after an incident.

Minimum detectable activity (MDA) values for each instrument were calculated and also the committed effective doses to which these would correspond, 24 hours after intake of soluble ^{137}Cs. This information was used to determine if the instruments tested are sensitive enough to be used to identify levels of ^{137}Cs in people where decorporation therapy could be considered. A 10 mSv intervention level (the level at which follow-up measurements would be required) was assumed.

The MDA values shown in Table 2 (30 cm monitoring distance) for whole body measurements show that values range from 140 kBq to 2200 kBq for an adult. If the ROI feature (available on three instruments) is used the MDAs are much lower at 10-14 kBq. The MDAs generally decrease with decreasing phantom size, with the values for the 3 month old infant being, on average, 45% lower than those of the adult, at 30 cm. This difference decreases to 30% at 1 m.

The RAM GENE-1 has been shown to be unsuitable for this type of measurement, as the detector response to the calibration phantoms was not significant. The MC-71 probe and identiFINDER^{ULTRA} are much less sensitive than the other five instruments, for example the MDAs at 30 cm are about 5x greater. The calculated MDAs for the 44A and 42B probes are quite low, about 100-200 kBq at 30 cm, and compare favourably with those of the more sophisticated and expensive instruments. The InSpector 1000, GR-135, and GR-130, which are all based on similar detectors, provide similar low MDAs, particularly if the ROI feature is used.

For instruments from which responses were significantly above background, MDAs at 1 m were about 5x higher than at 30 cm, and at 2 m were about 15x higher.

In the event that large numbers of members of the public require monitoring for ^{137}Cs, there could be some delay between the intake and the measurement. Assuming an intervention level of 10 mSv, calculated committed effective doses corresponding to the MDAs as measured following a delay of 24 hours (Tables 8-10), suggest the use of the InSpector 1000, GR-135, and GR-130, and the simpler and more numerous Thermo

Mini series instruments with type 44A and 42B probes for whole body measurements at a distance of 30 cm from the centre of the subject's chest.

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APPENDIX A

Methods, Results and Raw Data

A1 BACK-SCATTER: METHOD AND RESULTS

The chest only of the ^{137}Cs phantom was placed first on the floor and a reading was taken 30 cm above the surface of the part at 10 cm distance from the centre of the filling cap along the axis. A second reading was taken with the chest placed on a table. The measurements were repeated using the chest of the distilled water phantom, to check that the different measurement geometry was not affecting background count rate. For each measurement the count rate was integrated over 600 seconds.

The percentage difference between the count rate recorded on the floor and on the table was calculated. The difference in recorded counts from floor and table positions using the distilled water phantom chest ranged from 0.2 to 9.6%, with higher counts always from the floor measurement. The difference for the ^{137}Cs phantom ranged from 1.4 to 7.5% higher count rate for the floor position [Table A1]. Two of the instruments, the InSpector and MC71 probe registered slightly higher counts on the table.

The range of percentage difference observed in the count rates from the ^{137}Cs phantom and the distilled water phantom are similar and suggest that there is no significant effect from back-scatter of radiation from the floor.

However, given the slightly higher count rate observed for each instrument with the distilled water phantom placed on the floor, it would appear that there is some contribution to the count rate from radionuclides in the floor. This contribution is small, and with the addition of natural variation in background radiation, it can be assumed there that is no significant effect on the ^{137}Cs phantom counts.

Table A1 Sensitivity to back-scatter: % difference Floor : Table counts

Instrument	Distilled water chest	^{137}Cs chest
InSpector™ 1000	3.0	-2.0
Exploranium GR-135	4.8	4.1
Exploranium GR-130	0.2	4.4
identiFINDER	0.4	3.8
Mini MC71 end on	1.2	1.4
Mini MC71 lengthways	5.0	-3.6
Mini 44A	9.6	7.5
Mini 42B	3.8	5.4
RAM GENE-1	<1	<1

Note. 1. Measurements taken at 30 cm distance from surface for 600 s

2. n = 2

A2 BACKGROUND MEASUREMENTS: METHODS AND RESULTS

A2.1 Distilled water phantom background

Each instrument was used to measure the count rate for a distilled water-filled BOMAB phantom, in each of the age configurations. The positioning of the instruments relative to the phantom was the same as detailed in section 2.2.1 [*Measurement protocol*].

A2.2 Person background

Two measurements of a person lying on the floor in the place of the phantom were carried out for each instrument [Tables A2 to A10]. The probe was positioned facing the centre of the person's chest (at the abdominal end of the sternum) at 30 cm and 1 m height above the surface. All measurements were carried out over 60 seconds, except for those for the MC71, which were taken for 100 seconds.

The mean of the duplicate results was calculated (not shown). The difference between the mean of the two person backgrounds, at 30 cm and 1 m, for each instrument ranged from 0.5 to 10.2%. The difference showed no particular trend to a higher background count at either distance and measurements fell well within the range of the measurements taken with the distilled water phantom in place.

Table A2 InSpector: Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	131.0	136.0	135.5	137.0	141.0	139.0
	ROI	1.5	1.5	1.4	1.8	1.8	1.6
16 yr old	Full scale	133.0	140.5	133.0	137.5	NM	NM
14 yr old	Full scale	134.0	134.0	137.0	135.5	NM	NM
8 yr old	Full scale	136.0	137.0	133.5	135.0	NM	NM
4 yr old	Full scale	135.0	136.0	135.5	139.5	NM	NM
3 month old	Full scale	135.0	137.0	132.0	137.5	NM	NM
Person (bkg)	Full scale	136.5	135.5	137.5	139.5	NM	NM
	ROI	1.4	1.5	1.7	1.5	NM	NM

Note. NM = No measurement.

Table A3 GR-135: Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	44.7	47.5	48.6	47.7	49.4	49.0
	ROI	0.6	0.6	0.5	0.7	0.6	0.5
16 yr old	Full scale	46.7	47.1	50.0	48.4	NM	NM
14 yr old	Full scale	46.7	47.7	48.0	50.1	NM	NM
8 yr old	Full scale	45.7	47.6	48.7	49.0	NM	NM
4 yr old	Full scale	46.5	45.5	48.9	48.0	NM	NM
3 month old	Full scale	47.0	46.7	48.5	48.4	NM	NM
Person (bkg)	Full scale	46.1	46.5	49.2	50.0	NM	NM
	ROI	0.4	0.5	0.7	0.6	NM	NM

Note. NM = No measurement.

Table A4 GR-130: Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	50.1	50.4	52.3	50.9	56.4	54.8
	ROI	1.1	1.0	1.3	1.1	1.4	1.5
16 yr old	Full scale	50.0	50.8	53.2	53.0	NM	NM
14 yr old	Full scale	52.0	50.8	52.4	51.8	NM	NM
8 yr old	Full scale	51.9	50.5	53.2	52.0	NM	NM
4 yr old	Full scale	50.6	51.8	53.0	52.9	NM	NM
3 month old	Full scale	51.3	50.7	53.4	53.6	NM	NM
Person (bkg)	Full scale	50.8	51.9	52.6	53.2	NM	NM
	ROI	1.1	1.1	1.2	1.3	NM	NM

Note. NM = No measurement.

Table A5 identiFINDER: Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	189.6	186.4	188.9	186.7	191.9	188.3
16 yr old	Full scale	185.3	188.4	188.7	186.2	NM	NM
14 yr old	Full scale	187.2	185.5	186.6	186.7	NM	NM
8 yr old	Full scale	186.2	187.8	186.4	183.3	NM	NM
4 yr old	Full scale	185.5	187.3	183.0	189.8	NM	NM
3 month old	Full scale	185.3	188.8	189.0	183.3	189.5	187.2
Person (bkg)	Full scale	185.2	184.6	181.2	184.8	NM	NM

Note. NM = No measurement.

Table A6 MC71 (end on): Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	1.9	2.2	2.3	2.6	2.2	2.5
16 yr old	Full scale	2.4	2.3	2.3	2.1	NM	NM
14 yr old	Full scale	2.1	2.2	2.2	2.4	NM	NM
8 yr old	Full scale	2.7	1.8	2.3	2.1	NM	NM
4 yr old	Full scale	2.0	2.6	2.3	2.4	NM	NM
3 month old	Full scale	2.5	2.4	2.2	2.2	NM	NM
Person (bkg)	Full scale	1.9	2.5	2.2	2.3	NM	NM

Note. NM = No measurement.

Table A7 MC71 (lengthways): Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	2.4	2.2	2.7	2.3	2.4	2.4
16 yr old	Full scale	2.4	2.6	2.7	2.6	NM	NM
14 yr old	Full scale	2.8	2.6	2.7	2.9	NM	NM
8 yr old	Full scale	2.7	2.2	2.5	2.5	NM	NM
4 yr old	Full scale	2.9	3.0	2.6	2.8	NM	NM
3 month old	Full scale	2.6	2.9	2.6	2.6	NM	NM
Person (bkg)	Full scale	3.0	2.2	2.4	2.5	NM	NM

Note. NM = No measurement.

Table A8 44A: Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	4.9	5.3	5.0	4.1	4.8	4.8
16 yr old	Full scale	4.8	4.2	4.5	4.6	NM	NM
14 yr old	Full scale	5.1	5.0	4.6	4.6	NM	NM
8 yr old	Full scale	5.1	4.4	4.2	4.6	NM	NM
4 yr old	Full scale	4.7	4.8	4.8	4.5	NM	NM
3 month old	Full scale	4.7	4.3	4.6	4.8	NM	NM
Person (bkg)	Full scale	4.6	4.6	4.3	4.7	NM	NM

Note. NM = No measurement.

Table A9 42B: Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	1.5	1.8	1.9	1.7	1.6	1.8
16 yr old	Full scale	1.7	1.5	2.0	1.6	NM	NM
14 yr old	Full scale	1.8	2.4	1.7	2.0	NM	NM
8 yr old	Full scale	2.2	1.8	1.8	1.7	NM	NM
4 yr old	Full scale	1.7	1.9	1.6	1.9	NM	NM
3 month old	Full scale	1.6	1.8	1.5	2.1	NM	NM
Person (bkg)	Full scale	1.7	1.9	1.7	1.6	NM	NM

Note. NM = No measurement.

Table A10 RAM GENE-1: Background data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	<1	<1	<1	<1	NM	NM
16 yr old	Full scale	<1	<1	<1	<1	NM	NM
14 yr old	Full scale	<1	<1	<1	<1	NM	NM
8 yr old	Full scale	<1	<1	<1	<1	NM	NM
4 yr old	Full scale	<1	<1	<1	<1	NM	NM
3 month old	Full scale	<1	<1	<1	<1	NM	NM
Person (bkg)	Full scale	<1	<1	<1	<1	NM	NM

Note. NM = No measurement.

A2.3 Mean background counts

Since the background counts for each instrument were not significantly different for the three distances or the size of phantom, the mean of all the phantom measurements was taken for calculations.

Table A11 Mean background counts (cps)

Instrument	Scale	Mean background counts (cps)
InSpector	Full scale	135.9
	ROI	1.6
Exploranium GR-135	Full scale	47.8
	ROI	0.6
Exploranium GR-130	Full scale	52.1
	ROI	1.2
identiFINDER	Full scale	187.1
Mini MC71 end on	Full scale	2.3
Mini MC71 lengthways	Full scale	2.6
Mini 44A	Full scale	4.7
Mini 42B	Full scale	1.8
RAM GENE-1	Full scale	<1

Note. It was not possible to define an ROI on the instruments with no ROI result listed

A3 CALIBRATION RESULTS: RAW DATA

Raw data: not background subtracted. The BOMAB phantom activities used for this work are given in Table 1.

A3.1 Whole ^{137}Cs phantom calibration data

Table A12 InSpector: Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	953.5	947.5	340.5	338.5	205.0	217.5
	ROI	94.1	96.4	22.2	22.6	9.6	10.2
16 yr old	Full scale	955.0	899.5	322.5	308.5	NM	NM
	ROI	90.9	92.2	20.4	19.4	NM	NM
14 yr old	Full scale	767.5	779.5	287.0	282.0	NM	NM
	ROI	80.6	77.3	17.3	17.1	NM	NM
8 yr old	Full scale	493.5	487.5	218.0	213.0	NM	NM
	ROI	50.6	48.9	10.0	11.2	NM	NM
4 yr old	Full scale	384.0	385.5	189.0	181.5	NM	NM
	ROI	34.8	36.3	8.0	7.4	NM	NM
3 month old	Full scale	260.5	260.5	161.5	169.5	NM	NM
	ROI	19.8	20.2	4.7	4.0	NM	NM

Note. 1. ROI = 604.8 – 721.2 keV

2. NM = No measurement.

Table A13 GR-135: Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	554.5	553.1	172.5	172.1	92.5	91.9
	ROI	46.2	45.1	9.3	10.1	3.5	3.3
16 yr old	Full scale	533.4	534.1	164.2	163.2	89.2	89.2
	ROI	44.8	44.0	9.2	9.7	3.1	3.3
14 yr old	Full scale	463.0	464.8	140.7	141.5	81.4	82.0
	ROI	38.2	40.0	8.6	8.3	2.8	2.8
8 yr old	Full scale	279.2	282.5	95.5	97.8	NM	NM
	ROI	25.4	26.2	5.0	4.9	NM	NM
4 yr old	Full scale	206.7	207.3	83.6	83.2	NM	NM
	ROI	17.6	17.8	3.7	3.9	NM	NM
3 month old	Full scale	130.6	128.7	63.2	60.7	NM	NM
	ROI	10.4	10.8	2.0	1.4	NM	NM

Note. 1. ROI = 630.4 – 693.7 keV

2. NM = No measurement.

Table A14 GR-130: Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	642.4	653.4	202.5	200.2	105.3	106.8
	ROI	68.0	67.9	16.4	16.2	5.5	5.5
16 yr old	Full scale	622.4	616.6	184.5	188.5	104.3	101.1
	ROI	66.2	66.4	14.4	14.7	5.0	5.0
14 yr old	Full scale	529.1	522.8	160.9	161.6	93.8	91.1
	ROI	56.5	54.8	12.3	12.3	4.6	4.7
8 yr old	Full scale	290.7	296.4	107.7	110.2	72.3	69.6
	ROI	33.0	32.1	7.8	7.7	3.1	3.1
4 yr old	Full scale	234.6	233.3	92.2	90.9	68.0	67.1
	ROI	24.2	24.6	5.6	5.7	2.2	2.5
3 month old	Full scale	139.9	137.0	68.2	67.8	NM	NM
	ROI	13.8	12.4	3.6	3.5	NM	NM

Note. 1. ROI = 599 – 725 keV

2. NM = No measurement.

Table A15 identiFINDER: Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	619.4	626.5	294.0	295.4	224.2	227.7
16 yr old	Full scale	603.3	609.7	285.5	281.9	227.1	224.7
14 yr old	Full scale	540.1	537.6	261.1	261.5	216.6	216.8
8 yr old	Full scale	387.9	391.9	227.7	230.3	205.5	201.9
4 yr old	Full scale	312.0	316.7	214.4	213.0	198.2	202.8
3 month old	Full scale	250.5	251.1	195.9	198.5	194.5	193.0

Table A16 MC71 (end on): Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	4.6	5.2	3.1	3.1	2.3	2.7
16 yr old	Full scale	5.0	4.6	3.1	3.3	NM	NM
14 yr old	Full scale	4.2	4.0	2.8	3.4	NM	NM
8 yr old	Full scale	3.6	3.4	2.3	2.6	NM	NM
4 yr old	Full scale	3.1	2.9	2.5	2.2	NM	NM
3 month old	Full scale	2.4	2.6	2.1	2.2	NM	NM

Note. NM = No measurement.

Table A17 MC71 (lengthways): Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	7.6	7.9	3.7	3.9	2.8	2.9
16 yr old	Full scale	7.6	7.2	3.6	3.7	NM	NM
14 yr old	Full scale	6.8	7.0	3.8	3.6	NM	NM
8 yr old	Full scale	5.0	4.9	3.0	3.1	NM	NM
4 yr old	Full scale	4.0	4.2	3.2	2.9	NM	NM
3 month old	Full scale	3.5	3.6	2.6	3.1	NM	NM

Note. NM = No measurement.

Table A18 44A: Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	92.4	94.6	26.8	27.1	12.3	11.9
16 yr old	Full scale	88.7	88.1	25.7	24.8	11.1	11.7
14 yr old	Full scale	85.1	75.4	19.6	21.0	10.2	10.4
8 yr old	Full scale	39.5	39.7	12.0	12.2	7.1	6.7
4 yr old	Full scale	31.9	30.9	9.5	9.9	6.7	6.0
3 month old	Full scale	16.3	16.9	6.8	7.0	5.3	5.5

Table A19 42B: Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	23.1	22.7	7.6	7.1	3.8	3.8
16 yr old	Full scale	21.9	23.3	7.5	7.2	3.4	3.4
14 yr old	Full scale	17.9	17.6	6.2	5.7	3.0	3.2
8 yr old	Full scale	10.2	10.7	4.2	3.7	2.7	2.5
4 yr old	Full scale	7.9	7.8	2.8	2.8	2.2	2.1
3 month old	Full scale	4.5	4.6	2.3	2.0	2.1	2.2

Table A20 RAM GENE-1: Whole ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	2	2	1	1	<1	<1
16 yr old	Full scale	2	2	1	1	<1	<1
14 yr old	Full scale	<2	<2	<1	<1	NM	NM
8 yr old	Full scale	1	1	<1	<1	NM	NM
4 yr old	Full scale	1	1	<1	<1	NM	NM
3 month old	Full scale	<1	<1	<1	<1	NM	NM

Note. NM = No measurement.

A3.2 "Lung" ^{137}Cs phantom calibration data

Table A21 InSpector: "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	502.5	506.5	195.5	209.5	168.5	174.5
	ROI	44.0	45.8	7.2	8.5	5.4	5.8
16 yr old	Full scale	499.0	501.5	211.0	208.0	NM	NM
	ROI	44.1	44.1	7.9	8.0	NM	NM
14 yr old	Full scale	494.5	502.5	204.5	196.0	NM	NM
	ROI	44.3	44.1	7.8	8.4	NM	NM
8 yr old	Full scale	345.5	356.0	178.5	172.5	NM	NM
	ROI	30.4	32.4	6.0	5.7	NM	NM
4 yr old	Full scale	276.0	284.0	161.5	162.0	NM	NM
	ROI	21.5	21.4	4.8	4.3	NM	NM
3 month old	Full scale	241.0	237.0	158.5	159.5	NM	NM
	ROI	15.4	16.4	3.5	3.8	NM	NM

Note. 1. ROI = 604.8 – 721.2 keV

2. NM = No measurement.

Table A22 GR-135: "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	277.7	277.9	91.2	91.7	61.7	62.9
	ROI	21.8	21.4	3.8	3.7	1.5	1.0
16 yr old	Full scale	280.0	281.7	89.9	90.9	NM	NM
	ROI	20.3	21.3	4.0	3.9	NM	NM
14 yr old	Full scale	277.6	281.1	89.5	89.3	NM	NM
	ROI	19.6	20.6	4.0	4.0	NM	NM
8 yr old	Full scale	192.9	192.2	70.0	71.6	NM	NM
	ROI	17.0	16.5	2.6	2.9	NM	NM
4 yr old	Full scale	139.0	139.2	64.4	64.0	NM	NM
	ROI	10.7	10.5	2.1	2.1	NM	NM
3 month old	Full scale	116.4	115.7	58.6	59.0	NM	NM
	ROI	8.5	8.6	1.4	1.4	NM	NM

Note. 1. ROI = 630.4 – 693.7 keV

2. NM = No measurement.

Table A23 GR-130: "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	328.3	331.0	104.9	104.5	71.0	70.2
	ROI	31.9	33.2	6.4	6.2	2.4	2.7
16 yr old	Full scale	333.3	331.6	103.8	100.6	NM	NM
	ROI	32.4	31.4	5.9	6.2	NM	NM
14 yr old	Full scale	327.4	325.7	102.5	101.9	NM	NM
	ROI	30.4	31.8	6.1	6.5	NM	NM
8 yr old	Full scale	205.0	200.1	77.7	78.9	NM	NM
	ROI	21.2	21.6	4.6	4.2	NM	NM
4 yr old	Full scale	161.2	159.2	71.7	70.9	NM	NM
	ROI	15.4	15.6	3.2	3.1	NM	NM
3 month old	Full scale	122.0	121.2	66.0	65.6	NM	NM
	ROI	11.4	11.0	2.7	2.9	NM	NM

Note. 1. ROI = 599 – 725 keV

2. NM = No measurement.

Table A24 identiFINDER: "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	388.3	387.3	219.6	221.2	201.7	200.9
16 yr old	Full scale	389.4	391.7	221.8	218.4	204.0	204.6
14 yr old	Full scale	385.8	379.5	223.9	222.4	198.6	204.4
8 yr old	Full scale	310.4	316.2	204.9	202.6	196.3	197.4
4 yr old	Full scale	265.1	267.5	201.0	199.3	196.0	194.4
3 month old	Full scale	239.8	240.7	195.6	192.7	194.0	196.0

Table A25 MC71 (end on): "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	2.9	2.9	2.7	2.5	2.4	2.4
16 yr old	Full scale	3.6	3.2	2.2	2.8	NM	NM
14 yr old	Full scale	3.1	3.4	2.4	2.5	NM	NM
8 yr old	Full scale	2.7	3.0	2.6	2.4	NM	NM
4 yr old	Full scale	2.8	2.6	2.5	2.2	NM	NM
3 month old	Full scale	2.8	2.8	2.1	2.3	NM	NM

Note. NM = No measurement.

Table A26 MC71 (lengthways): "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	4.8	5.2	3.0	3.2	2.8	2.6
16 yr old	Full scale	5.4	5.2	2.9	2.8	NM	NM
14 yr old	Full scale	4.6	4.7	2.9	2.8	NM	NM
8 yr old	Full scale	4.1	4.0	2.6	2.7	NM	NM
4 yr old	Full scale	3.7	3.6	2.5	2.4	NM	NM
3 month old	Full scale	3.4	3.6	2.8	2.9	NM	NM

Note. NM = No measurement.

Table A27 44A: "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	49.9	50.1	11.7	12.5	7.6	7.2
16 yr old	Full scale	48.7	50.9	11.8	13.0	7.4	6.7
14 yr old	Full scale	48.0	47.2	11.5	11.7	6.9	7.8
8 yr old	Full scale	31.0	29.3	8.1	7.6	NM	NM
4 yr old	Full scale	21.0	20.4	7.0	7.3	NM	NM
3 month old	Full scale	14.5	14.2	6.6	6.2	NM	NM

Note. NM = No measurement.

Table A28 42B: "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	12.6	12.8	4.2	3.7	2.6	2.5
16 yr old	Full scale	13.6	13.2	4.0	4.0	2.6	2.3
14 yr old	Full scale	13.4	13.2	3.7	3.9	2.6	2.4
8 yr old	Full scale	8.4	8.3	2.9	2.6	NM	NM
4 yr old	Full scale	6.0	5.9	2.6	2.7	NM	NM
3 month old	Full scale	4.7	4.2	2.4	2.4	NM	NM

Note. NM = No measurement.

Table A29 RAM GENE-1: "Lung" ^{137}Cs phantom calibration data (cps)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	1	1	<1	<1	NM	NM
16 yr old	Full scale	1	1	<1	<1	NM	NM
14 yr old	Full scale	1	1	<1	<1	NM	NM
8 yr old	Full scale	<1	<1	<1	<1	NM	NM
4 yr old	Full scale	<1	<1	<1	<1	NM	NM
3 month old	Full scale	<1	<1	<1	<1	NM	NM

Note. NM = No measurement.

A4 DETECTOR EFFICIENCY

The detector counting efficiency (cps/kBq) of each instrument was calculated as:

background subtracted cps / kBq in appropriate BOMAB configuration

A4.1 Detector efficiency for whole body measurement

Table A30 InSpector: Detector efficiency for whole body measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.637	0.633	0.160	0.158	(0.054)	(0.064)
	ROI	0.072	0.074	0.016	0.016	0.006	0.007
16 yr old	Full scale	0.716	0.667	0.163	0.151	NM	NM
	ROI	0.078	0.079	0.016	0.016	NM	NM
14 yr old	Full scale	0.719	0.732	0.172	(0.166)	NM	NM
	ROI	0.090	0.086	0.018	0.018	NM	NM
8 yr old	Full scale	0.837	0.823	(0.192)	(0.181)	NM	NM
	ROI	0.115	0.111	0.020	0.023	NM	NM
4 yr old	Full scale	0.821	0.826	(0.176)	(0.151)	NM	NM
	ROI	0.110	0.115	0.021	0.019	NM	NM
3 month old	Full scale	(1.123)	(1.123)	(0.231)	(0.303)	NM	NM
	ROI	0.164	0.167	(0.028)	(0.021)	NM	NM

Note. 1. ROI = 604.8 – 721.2 keV

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. NM = No measurement.

Table A31 GR-135: Detector efficiency for whole body measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.395	0.394	0.097	0.097	(0.035)	(0.034)
	ROI	0.036	0.035	0.007	0.007	(0.002)	(0.002)
16 yr old	Full scale	0.424	0.425	0.102	0.101	(0.036)	(0.036)
	ROI	0.039	0.038	0.008	0.008	(0.002)	(0.002)
14 yr old	Full scale	0.473	0.475	0.106	0.107	(0.038)	(0.039)
	ROI	0.043	0.045	0.009	0.009	(0.003)	(0.003)
8 yr old	Full scale	0.542	0.550	(0.112)	(0.117)	NM	NM
	ROI	0.058	0.060	0.010	0.010	NM	NM
4 yr old	Full scale	0.526	0.528	(0.118)	(0.117)	NM	NM
	ROI	0.056	0.057	(0.010)	(0.011)	NM	NM
3 month old	Full scale	0.746	0.729	(0.139)	(0.117)	NM	NM
	ROI	0.089	0.092	(0.013)	(0.008)	NM	NM

Note. 1. ROI = 630.4 – 693.7 keV

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. NM = No measurement.

Table A32 GR-130: Detector efficiency for whole body measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.460	0.469	0.117	0.115	(0.041)	(0.043)
	ROI	0.052	0.052	0.012	0.012	(0.003)	(0.003)
16 yr old	Full scale	0.499	0.493	0.116	0.119	(0.046)	(0.043)
	ROI	0.057	0.057	0.012	0.012	(0.003)	(0.003)
14 yr old	Full scale	0.543	0.536	0.124	0.125	(0.047)	(0.044)
	ROI	0.063	0.061	0.013	0.013	(0.004)	(0.004)
8 yr old	Full scale	0.559	0.572	(0.130)	(0.136)	(0.047)	(0.041)
	ROI	0.074	0.072	0.015	0.015	(0.004)	(0.004)
4 yr old	Full scale	0.604	0.599	(0.133)	(0.128)	(0.053)	(0.050)
	ROI	0.076	0.077	(0.014)	(0.015)	(0.003)	(0.004)
3 month old	Full scale	0.791	0.765	(0.145)	(0.142)	NM	NM
	ROI	0.113	0.100	(0.021)	(0.021)	NM	NM

Note. 1. ROI = 599 – 725 keV

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. NM = No measurement.

Table A33 identiFINDER: Detector efficiency for whole body measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.337	0.343	(0.083)	(0.084)	(0.029)	(0.032)
16 yr old	Full scale	0.364	0.369	(0.086)	(0.083)	(0.035)	(0.033)
14 yr old	Full scale	0.402	0.399	(0.084)	(0.085)	(0.034)	(0.034)
8 yr old	Full scale	0.470	0.480	(0.095)	(0.101)	(0.043)	(0.035)
4 yr old	Full scale	(0.413)	(0.429)	(0.090)	(0.086)	(0.037)	(0.052)
3 month old	Full scale	(0.571)	(0.577)	(0.079)	(0.103)	(0.067)	(0.053)

Note. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

Table A34 MC71 (end on): Detector efficiency for whole body measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	(0.002)	(0.002)	(0.001)	(0.001)	NS	(0.0004)
16 yr old	Full scale	(0.002)	(0.002)	(0.001)	(0.001)	NM	NM
14 yr old	Full scale	(0.002)	(0.002)	(0.001)	(0.001)	NM	NM
8 yr old	Full scale	(0.003)	(0.003)	NS	NS	NM	NM
4 yr old	Full scale	(0.003)	(0.002)	NS	NS	NM	NM
3 month old	Full scale	NS	(0.003)	NS	NS	NM	NM

Note. 1. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

2. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

3. NM = No measurement.

Table A35 MC71 (lengthways): Detector efficiency for whole body measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	(0.004)	(0.004)	(0.001)	(0.001)	NS	NS
16 yr old	Full scale	(0.004)	(0.004)	(0.001)	(0.001)	NM	NM
14 yr old	Full scale	(0.005)	(0.005)	(0.001)	(0.001)	NM	NM
8 yr old	Full scale	(0.006)	(0.005)	(0.001)	(0.001)	NM	NM
4 yr old	Full scale	(0.005)	(0.005)	(0.002)	NS	NM	NM
3 month old	Full scale	(0.008)	(0.009)	NS	(0.004)	NM	NM

Note. 1. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

2. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

3. NM = No measurement.

Table A36 44A: Detector efficiency for whole body measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.068	0.070	0.017	0.017	(0.006)	(0.006)
16 yr old	Full scale	0.073	0.073	0.018	0.018	(0.006)	(0.006)
14 yr old	Full scale	0.091	0.081	0.017	0.019	(0.006)	(0.006)
8 yr old	Full scale	0.081	0.082	(0.017)	(0.018)	(0.006)	(0.005)
4 yr old	Full scale	0.090	0.087	(0.016)	(0.017)	(0.007)	(0.004)
3 month old	Full scale	0.105	0.110	(0.019)	(0.021)	(0.005)	(0.008)

Note. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

Table A37 42B: Detector efficiency for whole body measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.017	0.016	0.004	0.004	(0.002)	(0.002)
16 yr old	Full scale	0.018	0.019	0.005	0.005	(0.001)	(0.001)
14 yr old	Full scale	0.018	0.018	(0.005)	(0.004)	(0.001)	(0.002)
8 yr old	Full scale	0.020	0.021	(0.006)	(0.005)	(0.002)	(0.002)
4 yr old	Full scale	0.020	0.020	(0.003)	(0.003)	NS	NS
3 month old	Full scale	(0.025)	(0.025)	(0.004)	NS	NS	(0.004)

Note. 1. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

2. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

Table A38 RAM GENE-1: Detector efficiency for whole body measurement (cps/kBq)

All measured count rates not significantly above background (below critical limit (L_C)), 95% confidence.

A4.2 Detector efficiency for "lung" measurement

Table A39 InSpector: Detector efficiency for "lung" measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	1.007	1.018	(0.164)	(0.202)	(0.090)	(0.106)
	ROI	0.117	0.121	0.015	0.019	(0.011)	(0.012)
16 yr old	Full scale	0.998	1.005	(0.206)	(0.198)	NM	NM
	ROI	0.117	0.117	0.017	0.018	NM	NM
14 yr old	Full scale	0.986	1.007	(0.189)	(0.165)	NM	NM
	ROI	0.117	0.117	0.017	0.019	NM	NM
8 yr old	Full scale	1.161	1.219	(0.236)	(0.203)	NM	NM
	ROI	0.160	0.170	(0.024)	(0.023)	NM	NM
4 yr old	Full scale	(1.026)	1.085	(0.188)	(0.191)	NM	NM
	ROI	0.146	0.145	(0.024)	(0.020)	NM	NM
3 month old	Full scale	(1.197)	(1.152)	(0.258)	(0.269)	NM	NM
	ROI	0.158	0.169	(0.021)	(0.025)	NM	NM

Note. 1. ROI = 604.8 – 721.2 keV

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. NM = No measurement.

Table A40 GR-135: Detector efficiency for "lung" measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.632	0.632	(0.119)	(0.121)	(0.038)	(0.042)
	ROI	0.058	0.057	(0.009)	(0.009)	(0.002)	(0.001)
16 yr old	Full scale	0.638	0.643	(0.116)	(0.118)	NM	NM
	ROI	0.054	0.057	(0.009)	(0.009)	NM	NM
14 yr old	Full scale	0.632	0.641	(0.115)	(0.114)	NM	NM
	ROI	0.052	0.055	(0.009)	(0.009)	NM	NM
8 yr old	Full scale	0.804	0.800	(0.123)	(0.132)	NM	NM
	ROI	0.091	0.088	(0.011)	(0.013)	NM	NM
4 yr old	Full scale	0.668	0.669	(0.122)	(0.119)	NM	NM
	ROI	0.074	0.073	(0.011)	(0.011)	NM	NM
3 month old	Full scale	0.782	0.773	(0.123)	(0.128)	NM	NM
	ROI	0.090	0.091	(0.010)	(0.010)	NM	NM

Note. 1. ROI = 630.4 – 693.7 keV

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. NM = No measurement.

Table A41 GR-130: Detector efficiency for "lung" measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.759	0.767	(0.145)	(0.144)	(0.052)	(0.050)
	ROI	0.084	0.088	0.014	0.014	(0.003)	(0.004)
16 yr old	Full scale	0.773	0.768	(0.142)	(0.133)	NM	NM
	ROI	0.086	0.083	0.013	0.014	NM	NM
14 yr old	Full scale	0.757	0.752	(0.139)	(0.137)	NM	NM
	ROI	0.080	0.084	0.013	0.014	NM	NM
8 yr old	Full scale	0.847	0.820	(0.142)	(0.149)	NM	NM
	ROI	0.111	0.113	(0.019)	(0.017)	NM	NM
4 yr old	Full scale	0.800	0.785	(0.144)	(0.138)	NM	NM
	ROI	0.104	0.105	(0.014)	(0.014)	NM	NM
3 month old	Full scale	0.796	0.787	(0.158)	(0.154)	NM	NM
	ROI	0.116	0.112	(0.017)	(0.019)	NM	NM

Note. 1. ROI = 599 – 725 keV

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. NM = No measurement.

Table A42 identiFINDER: Detector efficiency for "lung" measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.553	0.550	(0.089)	(0.094)	(0.040)	(0.038)
16 yr old	Full scale	0.556	0.562	(0.095)	(0.086)	(0.047)	(0.048)
14 yr old	Full scale	0.546	(0.529)	(0.101)	(0.097)	(0.031)	(0.047)
8 yr old	Full scale	(0.683)	(0.715)	(0.099)	(0.086)	(0.051)	(0.057)
4 yr old	Full scale	(0.571)	(0.589)	(0.102)	(0.089)	(0.065)	(0.054)
3 month old	Full scale	(0.600)	(0.610)	(0.097)	(0.063)	(0.078)	(0.101)

Note. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

Table A43 MC71 (end on): Detector efficiency for "lung" measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	(0.002)	(0.002)	(0.001)	NS	NS	NS
16 yr old	Full scale	(0.004)	(0.002)	NS	(0.002)	NM	NM
14 yr old	Full scale	(0.002)	(0.003)	NS	NS	NM	NM
8 yr old	Full scale	(0.002)	(0.004)	NS	NS	NM	NM
4 yr old	Full scale	(0.004)	(0.003)	NS	NS	NM	NM
3 month old	Full scale	(0.006)	(0.006)	NS	NS	NM	NM

Note. 1. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

2. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

3. NM = No measurement.

Table A44 MC71 (lengthways): Detector efficiency for "lung" measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	(0.006)	(0.007)	(0.001)	(0.002)	NS	NS
16 yr old	Full scale	(0.008)	(0.007)	NS	NS	NM	NM
14 yr old	Full scale	(0.006)	(0.006)	NS	NS	NM	NM
8 yr old	Full scale	(0.008)	(0.008)	NS	NS	NM	NM
4 yr old	Full scale	(0.008)	(0.007)	NS	NS	NM	NM
3 month old	Full scale	(0.009)	(0.011)	NS	NS	NM	NM

Note. 1. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

2. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

3. NM = No measurement.

Table A45 44A: Detector efficiency for "lung" measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.124	0.125	(0.019)	(0.021)	(0.008)	(0.007)
16 yr old	Full scale	0.121	0.127	(0.020)	(0.023)	(0.007)	(0.006)
14 yr old	Full scale	0.119	0.117	(0.019)	(0.019)	(0.006)	(0.009)
8 yr old	Full scale	0.146	0.136	(0.019)	(0.016)	NM	NM
4 yr old	Full scale	0.119	0.115	(0.017)	(0.019)	NM	NM
3 month old	Full scale	0.112	0.109	(0.022)	(0.018)	NM	NM

Note. 1. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

2. NM = No measurement.

Table A46 42B: Detector efficiency for "lung" measurement (cps/kBq)

Configuration	Scale	30 cm		1 m		2 m	
Standard adult	Full scale	0.030	0.030	(0.007)	(0.005)	(0.002)	(0.002)
16 yr old	Full scale	0.032	0.031	(0.006)	(0.006)	(0.002)	(0.001)
14 yr old	Full scale	0.032	0.031	(0.005)	(0.006)	(0.002)	(0.002)
8 yr old	Full scale	0.036	0.036	(0.006)	(0.005)	NM	NM
4 yr old	Full scale	(0.031)	(0.030)	(0.006)	(0.007)	NM	NM
3 month old	Full scale	(0.034)	(0.028)	(0.007)	(0.007)	NM	NM

Note. 1. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

2. NM = No measurement.

Table A47 RAM GENE-1: Detector efficiency for "lung" measurement (cps/kBq)

All measured count rates not significantly above background (below critical limit (L_C)), 95% confidence.

A5 ERROR DETERMINATION

Three representative instruments were used to take measurements of the full ^{137}Cs standard adult phantom to determine the error if the probe is positioned incorrectly.

A5.1 Background subtracted data

Table A48 Error determination, GR-130: Full ^{137}Cs phantom bkgd subtracted (cps)

Detector position		30 cm		1 m		2 m	
Std position	Full scale	590.3	601.3	150.4	148.1	(53.2)	(54.7)
	ROI	66.8	66.6	15.2	14.9	(4.3)	(4.3)
10 cm side	Full scale	582.6	591.5	149.6	149.3	(53.8)	(55.6)
	ROI	65.9	65.1	14.8	14.8	(4.3)	(4.4)
10 cm up	Full scale	555.1	555.6	141.8	143.6	(52.6)	(50.4)
	ROI	63.5	61.5	13.9	14.8	(4.0)	(4.1)
10 cm down	Full scale	611.3	612.4	152.7	148.7	(56.8)	(57.1)
	ROI	66.4	67.8	15.4	16.1	(4.5)	(4.5)

Note. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

Table A49 Error determination, 44A: Full ^{137}Cs phantom bkgd subtracted (cps)

Detector position		30 cm		1 m		2 m	
Std position	Full scale	87.7	90.0	22.1	22.4	(7.7)	(7.2)
10 cm side	Full scale	86.2	87.7	22.4	21.9	(7.0)	(7.6)
10 cm up	Full scale	79.0	78.1	21.3	21.9	(6.8)	(7.1)
10 cm down	Full scale	90.8	92.0	23.8	23.6	(7.5)	(7.5)

Note. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

Table A50 Error determination, RAM GENE-1: Full ^{137}Cs phantom bkgd subtracted (cps)

Detector position		30 cm		1 m		2 m	
Std position	Full scale	(1)	(1)	NS	NS	NS	NS
10 cm side	Full scale	NS	(1)	NS	NS	NS	NS
10 cm up	Full scale	(1)	NS	NS	NS	NS	NS
10 cm down	Full scale	(1)	(1)	NS	NS	NS	NS

Notes. 1. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

2. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

A5.2 Error determination

Table A51 Difference in count rate with detector in standard and off-standard position (%)

Instrument / scale	Position	30 cm	1 m	2 m
GR-130				
Full scale	10 cm side	1.5	-0.1	-1.3
ROI		1.8	1.8	-1.2
Full scale	10 cm up	6.8	4.4	4.6
ROI		6.3	4.9	4.9
Full scale	10 cm down	-2.7	-1.0	-5.4
ROI		-0.6	-4.7	-5.9
44A				
Full scale	10 cm side	2.1	0.4	2.0
Full scale	10 cm up	11.5	3.1	6.5
Full scale	10 cm down	-2.9	-6.4	-0.9
RAM GENE-1				
Full scale	10 cm side	NS	NS	NS
Full scale	10 cm up	NS	NS	NS
Full scale	10 cm down	0.0	NS	NS

Note. 1. Probes were placed 10 cm up, towards the head; 10 cm down, towards the feet; and 10 cm to the side of the correct position at distances of 30 cm, 1 m, and 2 m.

2. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

The difference between the number of counts above background measured in the standard position and those measured in the off-standard positions is not significant. The most notable difference is seen at the '10 cm up' position at 30 cm (GR-130 = 6.8%, 44A = 11.5%). This is well within the level of variation in results observed in the background measurements. It is, therefore, likely that an error in positioning the detector of up to 10 cm in any direction from the standard position will still provide acceptable results.

A6 DETECTOR RESPONSE FOR A COMMITTED EFFECTIVE DOSE OF 10 MILLISIEVERTS

A 10 mSv intervention level (the level at which follow-up measurements would be required) was assumed in this document for illustrative purposes and the response of each instrument to the whole body activity which would give this dose was calculated as follows:

0.01 (Sv) / appropriate dose coefficient for subject age (Sv/Bq) = activity (Bq)

activity (Bq) x detector efficiency (cps/Bq) = detector response (cps)

The results are shown in Tables A52 and A53 for subject to detector distances of 30 cm and 1 m. The results do not account for any delay between intake and measurement, and do not include the background count rate, which is small compared to the response from ^{137}Cs in whole body for the measurements at 30 cm, but is more significant for measurements made at 1 m. Background count rates are given in Section A2.

As mentioned above, MDAs calculated for measurements at 2 m, except those for ROIs, would correspond to a dose of above 10 mSv, and therefore no calculations were performed for this distance.

Table A52 Detector response for a committed effective dose of 10 mSv at 30 cm (cps)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	1400	1600	2300	(1300)
	ROI	160	200	310	190
GR-135	Full scale	860	1100	1500	840
	ROI	76	100	160	100
GR-130	Full scale	1000	1200	1700	880
	ROI	110	140	210	120
identiFINDER	Full scale	740	910	(1200)	(650)
MC71 end on	Full scale	(4)	(5)	(7)	(2)◊
MC71 lengthways	Full scale	(9)	(11)	(14)	(10)
44A	Full scale	150	200	250	120
42B	Full scale	36	41	55	(28)
RAM GENE-1	Full scale	NS	NS	NS	NS

Note. 1. Values given to 2 significant figures.

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. ◊ Values derived from only one significant measurement.

4. No account has been taken of delay between intake and measurement.

5. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

Table A53 Detector response for a committed effective dose of 10 mSv at 1 m (cps)

Instrument	Scale	Std adult	14 yr old	4 yr old	3 month old
InSpector	Full scale	350	380	(450)	(300)
	ROI	35	40	56	(28)
GR-135	Full scale	210	240	(320)	(130)
	ROI	15	20	(30)	(12)
GR-130	Full scale	250	280	(360)	(160)
	ROI	26	29	(40)	(24)
identiFINDER	Full scale	(180)	(190)	(240)	(100)
MC71 end on	Full scale	(1)	(2)	NS	NS
MC71 lengthways	Full scale	(2)	(3)	(3)◊	(2)◊
44A	Full scale	38	40	(46)	(23)
42B	Full scale	9	(11)	(10)	(2)◊
RAM GENE-1	Full scale	NS	NS	NS	NS

Note. 1. Values given to 2 significant figures.

2. Values in brackets: derived from measurement results below detection limit (L_D), 95% confidence.

3. ◊ Values derived from only one significant measurement.

4. No account has been taken of delay between intake and measurement.

5. NS = Not significant: measured count rates below critical limit (L_C), 95% confidence.

APPENDIX B

Instruments

B1 MINI INSTRUMENTS: DIGITAL SCALER TYPE 6-90 WITH TYPE 42B PROBE

The 42B is well established in teaching, research, hospital and industrial laboratories. Its reliability and convenient design are particularly attractive for industrial hygiene applications or where budgets are tight. This probe detects very low gamma energies down to 5 keV.

Scale type	digital scaler: counts per selected time interval; analogue log: 0-2,000 counts s^{-1}
Probe material	aluminium - black anodised
NaI crystal size	23 mm dia. 1.0 mm thick
Window area	4.1 cm^2
Window weight	14 mg/cm^2 of Be
Crystal depth below front face	16 mm
Bkg shield thickness	3.1 mm lead
Photomultiplier type	EMI 9924B
Sensitivity	min. 5 keV gamma
Dimensions	monitor: 240 mm (w) x 120 mm (h) x 100 mm (d) probe: 40 x 187 mm
Weight	monitor: 1.4 kg

Thermo Electron Corporation, Bath Road, Reading, Berkshire, RG5 7PR, UK

B2 MINI INSTRUMENTS: DIGITAL SCALER TYPE 6-90 WITH TYPE 44A PROBE

The 44A is well established in teaching, research, hospital and industrial laboratories. Its reliability and convenient design are particularly attractive for industrial hygiene applications or where budgets are tight.

Scale type	digital scaler: counts per selected time interval; analogue log: 0-2,000 counts s^{-1}
Probe material	aluminium - black anodised
NaI crystal size	32 mm dia. 2.5 mm thick
Window area	8 cm^2
Window weight	14 mg/cm^2 of Al
Crystal depth below front face	3 mm
Bkg shield thickness	3.1 mm lead
Photomultiplier type	EMI 9902KB07
Sensitivity	15 – 250 keV gamma, >500 keV beta
Dimensions	monitor: 180 (w) x 165 (h) x 110 (d) mm overall probe: 50 x 180 mm
Weight	monitor: 1.0 kg

Thermo Electron Corporation, Bath Road, Reading, Berkshire, RG5 7PR, UK

B3 MINI INSTRUMENTS: DIGITAL SCALER TYPE 6-90 WITH ENVIRONMENTAL RADIATION MC-71 PROBE

The MC-71 probe with its low inherent background GM tube, is intended for environmental monitoring of low level gamma radiations.

Scale type	digital scaler: counts per selected time interval; analogue log: 0-2,000 counts s^{-1}
G-M tube	low inherent background, halogen quenched, energy compensated; forward axial response at 60 keV = approx. 40% of radial response
Sensitivity	^{137}Cs 15.7 counts s^{-1} $\mu Gy\ h^{-1}$
Energy range	55 keV to 1.25 MeV
Dimensions	240 x 120 x 100 mm
Weight	1.4 kg

Thermo Electron Corporation, Bath Road, Reading, Berkshire, RG5 7PR, UK

B4 SAIC CANADA: EXPLORANIUM™ GR-130 MINISPEC

The GR-130 is a hand-held spectrometer that can be used to locate a radioactive source, determine the exposure hazard level using the dose-rate meter, and identify nuclides for risk assessment. It is used primarily in first responder, customs, security, and health-physics applications.

Scale type	digital with spectrum: cps
Probe	integral
NaI crystal size	38 x 38 x 51 mm
Sensitivity	80 cps per 1 MBq at 1 m distance using ^{137}Cs
Dimensions	172 x 229 x 102 mm
Weight	2 kg including batteries and all detectors

6108 Edwards Blvd., Mississauga, Ontario L5T 2V7, Canada

B5 SAIC CANADA: THE IDENTIFIER EXPLORANIUM™ GR-135 RADIOACTIVE ISOTOPE IDENTIFICATION DEVICE (RIID)

The GR-135 is a hand-held spectrometer designed for the same purposes as the GR-130.

Scale type	digital with spectrum (with scale): cps
Probe	integral
NaI crystal size	38 mm dia. x 57 mm long
G-M tube	13 x 50 mm, energy compensated
Energy range	50 keV – 3.0 MeV
Dimensions	170 x 235 x 110 mm
Weight	2.4 kg including batteries and all detectors

6108 Edwards Blvd., Mississauga, Ontario L5T 2V7, Canada

B6 SOUTHERN SCIENTIFIC LTD: IDENTIFINDER$^{ULTRA\ TM}$

The identiFINDER™ is a hand-held digital gamma spectrometer and dose-rate meter. It allows the user to locate and identify a radioactive source. The ^{ULTRA} model incorporates a method of stabilization that does not require a radioactive source of any type.

Scale type	digital: cps
Probe	integral
NaI crystal size	35.5 x 50 mm
G-M tube	
Sensitivity	^{137}Cs MDL 26.072 Bq/m^2
Energy range	15 keV – 3.0 MeV
Dimensions	235 x 93 x 75 mm
Weight	1.25 kg including batteries and detectors

Scientific House, Rectory Farm Road, Sompting, Lancing, W. Sussex BN15 0DP

B7 CANBERRA UK: INSPECTOR™ 1000

The InSpector™ 1000 is a hand-held spectrometer for use primarily in first responder, customs, security, and health-physics applications. Designed for isotope identification and location with dose-rate and count rate displays.

Scale type	digital: cps
Probe	external
NaI crystal size	51 x 51 mm
G-M tube	
Energy range	50 keV – 3 MeV
Dimensions	monitor: 190 x 165 x 64 mm
Weight	2.2 kg including batteries and detectors

Building 528.10 Unit 1, Harwell I. B. Centre, Didcot, Oxfordshire OX11 OTA UK

B8 ROTEM INDUSTRIES LTD: RAM GENE-1 CONTAMINATION AND RADIATION METER

The RAM GENE-1 is designed for use in nuclear medicine, molecular biology laboratories, nuclear materials transportation, etc, for surface contamination and area monitoring. It is equipped with a dose-rate meter. This instrument has been issued to all hospital accident and emergency units in England and Wales.

Scale type	digital: cps
G-M tube	pancake (NRC 2006 or equiv.); 44.5 mm effective dia.
Window weight	1.5 - 2 mg/cm^2 of mica protected by stainless steel mesh
Sensitivity	Approx. 5.8 cps/μSv/hr - ^{137}Cs
Dimensions	110 x 67 x 74 mm
Weight	0.340 kg

Rotem Industrial Park, P.O.Box 9046, Beer Sheva 84190, Israel