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PHE Facility for Rapid Monitoring of Internal Contamination in People

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Abstract

Public Health England has developed a facility for rapidly monitoring people for internal contamination that uses a 51 mm diameter by 51 mm long sodium iodide based monitoring instrument. For many gamma emitting radionuclides this facility could be used to identify people who require medical assessment and, in the case of intakes of radiocaesium, those who would benefit from decorporation therapy.

This monitoring facility could be quickly deployed to the scene of an incident as comparatively little equipment is required and operation does not require specialist skills.

An evaluation has shown the instrument can detect activities of caesium-137 in people which would result in committed effective doses of less than 1 millisievert (mSv) assuming default intake parameters for times between intake and screening of up to 14 days.

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Executive Summary

The Centre for Radiation, Chemical and Environmental Hazards of Public Health England has developed a facility for rapidly monitoring people for internal contamination that uses a 51 mm diameter by 51 mm long sodium iodide based hand-held instrument. This facility, which consists of 6 monitoring systems, each comprising a sodium iodide instrument mounted on a purpose built support, can be used for monitoring for activity in the whole body and iodine-131 in the thyroid and can be adjusted to suit people of all ages.

This facility could be quickly deployed to the scene of an incident as comparatively little equipment is required and operation does not require specialist skills. The instrument supports have been made to allow accurate positioning of the detector in front of a person, which produces more accurate results.

An evaluation has shown the instrument can detect activities which would result in committed effective doses of less than 1 mSv for caesium-137, assuming default intake parameters and times between intake and screening of up to 14 days. Similar performance would be expected for other beta/gamma or gamma only emitting radionuclides, providing the radionuclide emits at least one gamma ray with energy above about 200 keV with high yield. This performance would allow people to be identified who require medical assessment or treatment to increase excretion of radionuclides (decorporation). If worst case intake parameters are assumed, in the absence of better information, it would still be possible to identify people who require medical assessment for most beta/gamma or gamma only emitting radionuclides. It is expected that people found to have significant activity in their body would be selected for more accurate measurements before decisions are made on the need for treatment.

This monitoring facility is not sensitive enough for use following intakes of any alpha emitting radionuclides, but could be used to identify people who require medical assessment after intake of the beta emitting radionuclide strontium-90. It is also incapable of quantifying individual radionuclides in a mixture, but in this case could still be used to find the most highly contaminated people for measurement on equipment capable of spectrometry.

This report describes the monitoring facility and gives details of the monitoring procedure which would be used. Calibration factors are listed so that activities in the body can be calculated for people of all ages for activity in the whole body for cobalt-60, selenium-75, strontium-90, caesium-137 and iridium-192, as well as iodine-131 in the thyroid.

Performance has been evaluated by calculating approximate detection limits for measurements of internal contamination in people and the doses which correspond to a measurement at the level of the detection limit. These doses are calculated using intake parameters which give the highest possible dose per unit measurement as well as for more likely intake parameters.

Details of how the facility would be transported and preparations prior to monitoring are given, as well as a detailed monitoring procedure. Report forms are provided to record the results of monitoring for both iodine in the thyroid and activity in the whole body.

Contents

1 Introduction

Following an incident in which radioactive material is released to the environment it is likely that monitoring of internal contamination levels in people will be required. The immediate aim is to identify people who could have internal contamination levels high enough to require medical assessment. Monitoring to identify these people should be carried out as soon as possible. To achieve this it is expected that the monitoring would be done at a radiation monitoring unit (RMU) set up close to the location of the incident (Rojas-Palma et al, 2009; Thompson et al, 2011).

For radionuclides which emit gamma rays of energy greater than about 200 keV measurements can be made by placing suitable detectors close to the person. PHE has several facilities for monitoring people for internal contamination. The most sensitive of these are laboratory based, well-shielded systems – see, for example, PHE (2014). PHE has similar facilities which can be deployed to an RMU. The transportable whole body monitor (Youngman, 2002) has sensitivity similar to laboratory based systems but is difficult to deploy rapidly as heavy lead shielding is used. More recently, PHE has produced calibrations and procedures to allow radionuclide identifiers to be used as whole body monitors (Youngman, 2008). This equipment can be battery powered and is small and so can easily be deployed to an RMU. All of these systems use high resolution gamma spectrometry and so can identify and quantify individual radionuclides in mixtures.

A problem of using complex equipment for internal contamination monitoring is that costs are high and operation requires specialist staff. As a consequence, the number of monitoring systems which can be operated is small with a corresponding low rate at which people can be monitored.

Another approach for monitoring people is to use simpler hand-held radiation monitors (CDC, 2010; Youngman et al, 2011). Although these monitors are much less sensitive than the PHE spectrometry based equipment, they can still be capable of detecting people who require medical attention (Youngman et al, 2011). This equipment can also be used to select people for more accurate measurement with the spectrometry based systems. As hand-held monitors are relatively inexpensive and are simple to operate, it is possible to deploy greater numbers of systems and therefore to increase the rate at which people can be monitored.

For alpha emitting and pure beta emitting radionuclides, measurements with hand-held radiation monitors are not sufficiently sensitive (with the exception of measuring strontium-90). For some of these radionuclides more sensitive detectors could be used following their transport to the incident location or, alternatively, people could be sent to laboratory based facilities. Where measurements with hand-held instruments or spectrometry based monitoring systems do not provide adequate sensitivity, it is probable that measurement of activity in a urine sample would be used to determine dose.

This report describes a newly developed PHE facility for monitoring people for internal contamination. It makes use of a 51 mm diameter by 51 mm long sodium iodide [NaI(Tl)] based hand-held monitor coupled with a digital meter. The detector is mounted in a frame which allows easy positioning in front of a person for either whole body or thyroid monitoring. Calibration factors for this facility are presented for radionuclides which are believed most likely to be used in a deliberate release. The performance is determined by calculating the

committed effective doses which correspond to an intake at the detection limit. Doses are calculated assuming default model parameter values describing the intake and also for parameter values which give the highest dose. The latter, more conservative method of dose assessment could be used to identify people who require medical assessment in situations where little information is available about the physicochemical characteristics of the material to which they have been exposed (Youngman et al, 2011).

It should be noted that, for all incidents where people have been contaminated with radioactive material, the removal of significant contamination on the skin and clothing is more urgent than monitoring for internal contamination. Furthermore, decontamination procedures should not be delayed by monitoring for either contamination on the skin and clothing or internal contamination.

2 Description of Equipment

2.1 Hand-held detector

The hand-held detector chosen for this facility is based on a 51 mm diameter by 51 mm long sodium iodide [NaI(Tl)] crystal. Previous work has shown that this type of detector is well suited to detection of gamma emitting radionuclides in people (Youngman et al, 2011). Larger detectors would be more sensitive, but are more expensive and heavier. The detector used is the PM11 coupled with a DA-2000 survey meter (Rotem Instruments, Israel). This particular instrument was chosen as it has been adopted as standard equipment for routine radiological protection work at PHE and so is available in relatively large numbers. Other instruments of similar design could also be used providing calibration factors are available. The DA-2000 meter is digital and so is much easier to use in a quantitative way than an analogue meter which typically has a semi-logarithmic scale. In addition, with this meter it is possible to integrate the count rate over a set time interval, so improving the detection limit.

Each detector is fitted with a lead sleeve collimator with a thickness of 5 mm and length of 80 mm. The presence of the collimator reduces the background count rate by about a factor of 2.5 by shielding the detector from photons entering from the side. The presence of the collimator reduces the chance of environmental contamination interfering with the measurement, with the possibility of producing incorrect quantification of activity in people.

2.2 Detector support frame

Six support frames for the detectors have been built (Figure 1). These are designed to hold the detector in a stable way and allow accurate positioning of the detector in front of a person. Accurate positioning would be much more difficult to achieve if the detectors were hand-held and use of a support frame avoids any manual handling issues for monitoring staff. The support frames allows the detector to be positioned to suit people with a very wide range of heights as the detector is mounted on a vertical slide assembly. For measurements of gamma emitting radionuclides in the whole body and radioiodine in the thyroid, the person can be seated or standing. Standing allows more rapid throughput, but seating is preferred as uncertainties caused by movement of the person are reduced. The detector can also be

readily adjusted to increase or decrease the distance to the person; this allows fine tuning of the person to detector distance without the need to move the person.

If necessary, measurements could be made using the detector without the support frame. This would result in a greater measurement uncertainty as the distance from the person to the detector is more difficult to control.

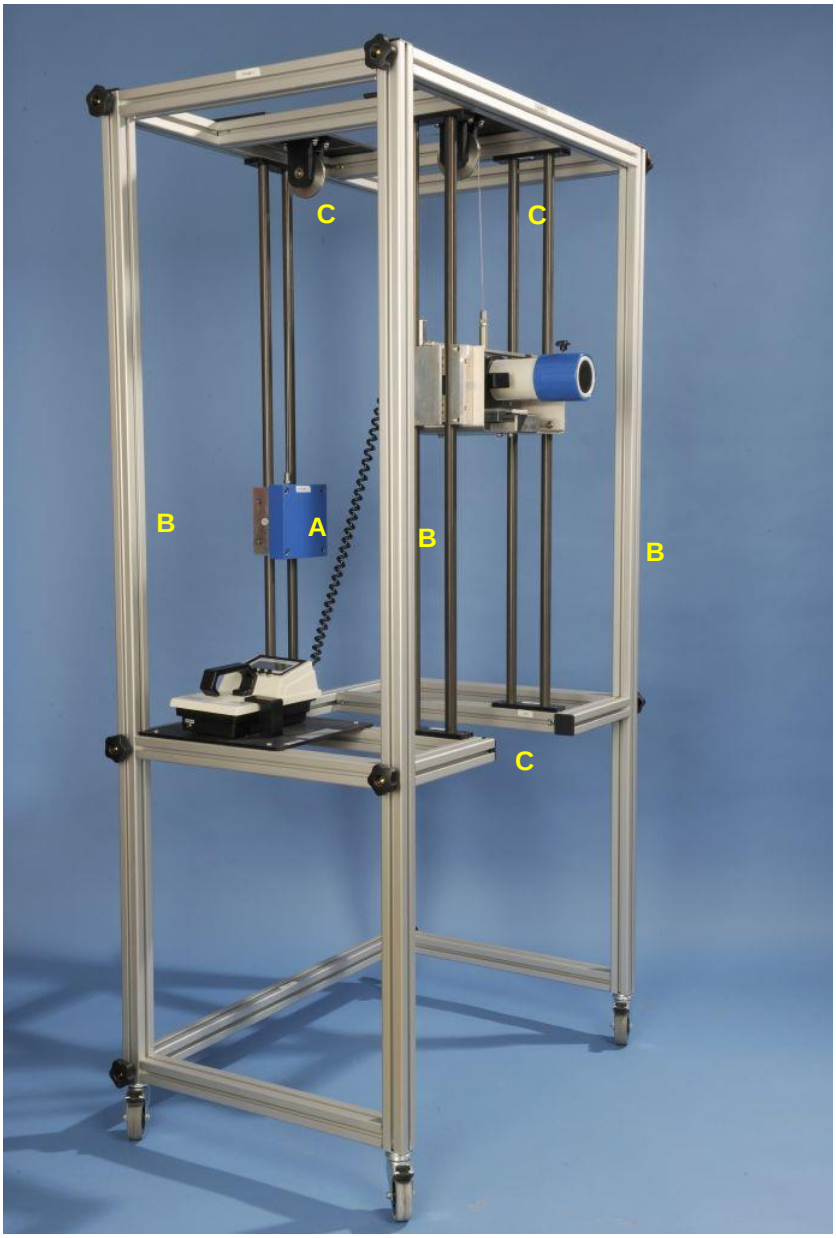

Figure 1: Detector support frame and PM11 radiation monitor
A: lead counterbalance weight B: leg sections C: main slide section

3 Transport

The PM11 probe and DA-2000 survey meter (Figure 2) are readily transported in a small suitcase.

Figure 2: PM11 scintillation probe and DA-2000 survey meter

The support frames can be transported in a partially or fully dismantled state, depending on availability of vehicles. When partially dismantled, the lead counterbalance weight (labelled A in Figure 1) and leg sections (B) are removed to leave the main slide section intact (C). When either partially or fully dismantled, a single frame would fit into a standard estate sized vehicle.

Assembly from a partially dismantled state takes approximately 5 minutes, and from a completely dismantled state takes approximately 30 minutes. When assembled, the support frames can easily be moved using built-in castors.

4 Preparations Before Monitoring

In the event of a radiation emergency, monitoring would normally be done at an RMU (Thompson et al, 2011). The area designated for internal contamination monitoring should be partitioned from other areas and unnecessary furniture removed. Disposable floor coverings should be used and chairs provided for people waiting for monitoring must be covered to allow for decontamination. More detail on setting up an RMU can be found in Thompson et al (2011).

Unless it is expected that levels of internal contamination in everyone selected for monitoring will be very low, a distance of 5–10 m should be allowed between individual monitoring stations and also between monitoring stations and people waiting for monitoring. This prevents the possibility of anyone with particularly high levels of internal contamination affecting the measurements. In the case of young children a parent or guardian can be allowed closer but should be monitored first to ensure their presence will not affect the measurement of the child.

5 Measurement Geometries

5.1 Gamma emitting radionuclides in the whole body

For radionuclides other than radioiodine, the detector height is adjusted so that the midline of the detector is directed at the centre of the chest (see Figure 3). The distance between the person and the end of the detector is then adjusted to 30 cm. When using the support frame, the person to detector distance can be finely adjusted using the horizontal slide mechanism. The person may be seated or standing for measurements.

Figure 3: Set-up for measurement of gamma emitting radionuclides in the whole body

5.2 Radioiodine in the thyroid

For measurements of radioiodine in the thyroid, the detector must be positioned close to the skin at the base of the neck (see Figure 4). The person can be seated or standing, although particularly tall people may need to be seated. If the measured count rate is above 100 s^{-1} then the measurement should be repeated using a distance of 10 cm. This gives more accurate results as the variation in position and depth of the thyroid has a smaller effect on the count.

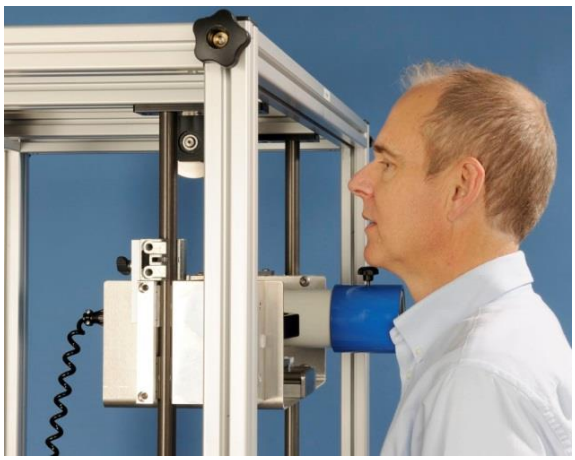

Figure 4: Set-up for measurement of radioiodine in the thyroid

6 Background

According to IEC Standard 61563 (IEC, 2001) the detection limit as defined by the ISO (ISO, 2010) of a gross count instrument (A_{min}) is calculated according to equation 1 such that there is a 95% chance that an indication of this count rate is not produced by background alone.

$$A_{min} = 3.29 \times C \sqrt{\frac{2\sum_{i=1}^{n}(N_{bi} - \bar{N}_b)}{(n-1)}} \quad (1)$$

where n = number of background readings
N_{bi} = ith background measurement expressed in s^{-1}
C = activity concentration conversion factor in $kg^{-1}\ Bq^{-1}\ s^{-1}$
$\bar{N}_b$ = mean background value for n measurements expressed in s^{-1}

From equation 1 the number of counts which indicate that the count is not produced by background alone (N_{min}) is given by

$$N_{min} = 3.29 \sqrt{\frac{2\sum_{i=1}^{n}(N_{bi} - \bar{N}_b)}{(n-1)}} \quad (2)$$

To decrease the probability of false positives, the factor of 3.29 can be increased to 4.68 so that the chance of a false positive is reduced to 1%. For the PM11 detector in a normal room environment the average background is approximately 90 s^{-1} and the additional (net) count corresponding to a 99% chance that an indication of this count rate is not attributable to background is approximately 9 s^{-1}.

With the sleeve collimator in place the typical background is reduced to approximately 40 s^{-1} and the variation in background count is similar to the uncollimated detector so that the additional count corresponding to a 99% chance remains at approximately 9 s^{-1}.

7 Measurement Procedure

The procedure for monitoring people for internal contamination has been adapted from an earlier report (Youngman et al, 2011).

The steps below should be followed in the order shown.

1 ***Has the radionuclide been identified with a high degree of confidence?*** If not, urgently obtain expert help to identify the radionuclide positively. Prior to identification of the radionuclides the methods described here can be used to identify those who are most contaminated

2 ***Estimate the elapsed time since intake of radioactive material.*** It is important to have an estimate of the time between the original contamination event and the time that measurements are made which is as reliable as possible. The day that the incident is discovered may not be the day of intake

3 ***Perform battery check and check source measurement.*** Turn on the radiation survey monitor, and perform a check of the detector battery function. If a portable radioactive check source is available, move that source closer to and further away from the front of the detector surface to ensure that the registered count rate increases and decreases accordingly

4 ***Establish the background count rate for the detector and monitoring location.*** Take a background reading of a person known not to be contaminated. This reading should be obtained prior to the introduction of any potentially contaminated individuals into the monitoring location. Record this value as the background count rate (BCR) in units of counts per second (cps). If it is suspected that the monitoring environment has become contaminated then this background check should be repeated and in any case repeated every hour. Detailed instructions for operating the rate meter are given in Appendix A

If time allows, a series of 10 background counts can be made and the count rate corresponding to a 99% chance that the measured count rate is not entirely due to background calculated using the equation in Section 6

5 ***Ensure adequate distance between the person being monitored and people waiting.*** Each person should be taken individually to the monitoring area, maintaining a distance of about 5–10 m between the person being monitored and other potentially contaminated people. In the case of young children a parent or guardian can be closer than this, but the parent or guardian should be monitored first to ensure their presence will not affect the measurement of the child

6 ***Position the detector.*** Hold the detector 30 cm from the centre of the chest (Figure 3). If monitoring for iodine-131 hold the detector close to the skin at the base of the neck (Figure 4). Note that the thyroid is positioned below the Adam's apple and above the clavicles. For iodine-131, if the count rate is above 100 s^{-1} then repeat using a distance between the detector and neck of 10 cm

7 ***Record the measurement.*** Use the procedure in Appendix A to make a measurement and record the results on the forms shown in Appendix B. The background count rate or BCR (see step 4 above) must be subtracted from the total count rate (TCR) measurement, to yield a net count rate (NCR):

Net count rate (NCR) = Total count rate (TCR) – Background count rate (BCR)

If the NCR is greater than or equal to 9 s^{-1} activity has been detected, if less than 9 s^{-1} then activity has not been detected. Record the results on the forms shown in Appendix B

8 ***Activity detected.*** If count rates significantly above background are found then the measurement should be repeated making sure that other people are at least 5 m distant

9 ***Calculate activity and dose.*** The net count rate (NCR) from step 7 can be used with calibration factors (Section 8) to calculate the activity of the radionuclide. Doses may also be calculated from measurement results using the computer code ERIDAS (Youngman et al, 2007) or another code for calculating dose from measurements of internal contamination. Alternatively, count rates which correspond to particular actions such as referral for medical assessment may have been prepared to allow direct comparison with the measured count rate

8 Calibration Factors

8.1 Activity in the whole body

Calibration factors for activity in the whole body were determined for caesium-137 (^{137}Cs), strontium-90/yttrium-90 (^{90}Sr in equilibrium with ^{90}Y) and cobalt-60 (^{60}Co) using bottle mannequin absorption (BOMAB) phantoms. The BOMAB phantom representing an adult consists of 10 cylindrical or ellipsoid bottles. BOMAB phantoms for adults were adapted to represent children of different ages by removing or replacing sections of the phantoms as described elsewhere (Youngman, 2002). Calibration factors for activity in the whole body for the radionuclides cobalt-60, selenium-75 (^{75}Se), strontium-90/yttrium-90, caesium-137, iridium-192 (^{192}Ir), radium-226 (^{226}Ra), thorium-228 (^{228}Th), thorium-232 (^{232}Th), neptunium-237 (^{237}Np) and americium-241 (^{241}Am) were determined using mathematical methods (Youngman et al, 2011). The mathematical calculations of efficiency were validated by comparing measured count rates of point sources with those produced using a mathematical model of the detector and also by comparing physical calibrations for cobalt-60, strontium-90/yttrium-90 and caesium-137 with mathematical calculations. Table 1 gives calibration factors for activity in the whole body for a range of ages from infant to adult. Calibration factors for the other radionuclides mentioned above are not shown as it was found that for these radionuclides the detectors were not sensitive enough to be used to identify people who require medical assessment (see Section 11).

Table 1: Calibration factors for radionuclides in the whole body for a PM11 detector and collimator

	Calibration factors (s^{-1} kBq^{-1})				
	Radionuclide				
Age	Cobalt-60	Selenium-75	Strontium-90/ yttrium-90	Caesium-137	Iridium-192
Adult	1.1	1.3	0.015	0.50	1.4
16 years	1.2	1.4	0.016	0.53	1.6
14 years	1.3	1.5	0.018	0.58	1.7
12 years	1.6	1.8	0.023	0.69	2.0
10 years	1.8	2.0	0.029	0.65	2.1
8 years	1.5	1.8	0.025	0.63	2.0
6 years	1.6	–	0.026	0.68	–
4 years	1.5	1.7	0.020	0.83	1.9
2 years	1.6	–	0.019	0.94	–
1 year	1.9	1.9	0.026	0.83	2.0
6–9 months	2.0	2.1	0.022	0.73	2.2
3 months	2.3	2.2	0.026	0.96	2.3
Infant	2.1	–	0.030	1.01	–

8.2 Activity in the thyroid

Calibration factors for iodine-131 in thyroid were determined using measured count rates for a thyroid phantom containing known quantities of iodine-131. This method is described in detail in Youngman (2012). The depth of the thyroid gland can be varied to simulate activity in people of different ages as the thickness of overlying tissue is known to vary.

Table 2: Calibration factors for iodine-131 in the thyroid for a PM11 detector and collimator

Age	Neck to detector distance	Calibration factors (s^{-1} kBq^{-1})
> 18 years	Close	34
> 18 years	10 cm	7.1
< 18 years	Close	55
< 18 years	10 cm	8.8

9 Records

Immediately before or after the monitoring procedures which are conducted at the RMU, personal information will be taken from each individual so that they can be identified for any necessary medical assessment or additional monitoring. At the beginning of the RMU process, each person will be assigned a unique code which can then be used on the results of monitoring and on the record of personal details so that results can be matched to an individual.

Thompson et al (2011) give details of methods for recording and reporting measurement results and also report forms for recording the results of whole body measurements and radioiodine in the thyroid. These forms are reproduced in Appendix B. The system of action levels used in these report forms is as described in Rojas-Palma et al (2009).

Following the completion of monitoring, each person would be given a form which summarises the results of monitoring and gives details of any further actions which are needed, such as further assessment. A copy of a suitable form can be found in Thompson et al, 2011 (Appendix E).

10 Performance

10.1 Detection limit

The detection limits for radionuclides in the body may be obtained by combining the count rate corresponding to a 99% chance that a positive net measurement is not attributable to background (Section 6) with the corresponding calibration factor (Section 8). These values are given in Table 3 for each radionuclide and for selected ages.

Table 3: Detection limits for radionuclides in the body* for a PM11 detector and collimator

	Limit of detection† (kBq)		
	Age		
Radionuclide	1 year	10 years	20 years
Cobalt-60	4.7	5.0	8.3
Selenium-75	4.7	4.5	7.0
Strontium-90/yttrium-90	340	310	600
Iodine-131	0.16	0.16	0.30
Caesium-137	11	14	18
Iridium-192	4.5	4.8	6.4

* For activity in the thyroid for ^{131}I with the detector held close to the neck and in the whole body for the other radionuclides

† Detection limits are calculated for approximately the 99% confidence level, such that if activity is present at a level equal to the detection limit it will be identified in 99 out of 100 measurements

10.2 Minimum detectable doses

In order to evaluate the usefulness of this monitoring facility following an incident where people may be internally contaminated, doses corresponding to a measurement at the detection limit have been calculated (minimum detectable dose). These doses have been calculated using two sets of assumptions about the route of intake, particle size and lung solubility type, ie

a using 'default' absorption types for intakes by inhalation given in ICRP Publication 119 (ICRP, 2012) and assuming a particle size (activity median aerodynamic diameter, AMAD) of 5 µm

b using 'worst case' parameters where the AMAD, absorption types and route of intake are selected to give the highest dose per unit measured activity, as described in Youngman et al, 2011 (Appendix I)

Committed effective doses for an intake at the level of the detection limit calculated using default intake parameters are presented in Table 4 and for worst case intake parameters in Table 5, for people of 3 ages and for 3 delays between intake and measurement. For both sets of assumptions, the values for the fraction of radionuclide reaching blood (f_1) are the ICRP default values (ICRP, 2012). The worst case assumptions would be appropriate when there is a complete lack of information on the physical and chemical properties of the released radionuclides; this may well be the case for deliberate release. Using worst case parameters is likely to lead to an overestimate of dose. For releases where more information is known about the physical and chemical properties, such as an accidental release from a nuclear power station, then default intake parameters are likely to give a more accurate estimate of dose. As information becomes available about the release then it will be possible to refine the intake assumptions to give more accurate dose assessments.

Table 4: Dose corresponding to a measurement equal to the detection limit for a PM11 detector and collimator assuming 'default' intake parameters

Time between intake and measurement (days)	Committed effective dose (mSv)		
	Age		
	1 year	10 years	20 years
Cobalt-60	*Assuming absorption type M, AMAD of 5 µm and f_1 = 0.1*		
1	0.4	0.2	0.3
7	1.4	0.7	1.0
14	1.6	0.8	1.3
Selenium-75	*Assuming absorption type F, AMAD of 5 µm and f_1 = 0.8*		
1	0.07	0.03	0.02
7	0.11	0.05	0.03
14	0.13	0.06	0.04
Strontium-90/ yttrium-90	*Assuming absorption type F, AMAD of 5 µm and f_1 = 0.3*		
1	44	35	46
7	93	66	110
14	120	79	150
Iodine-131	*Assuming absorption type F, AMAD of 5 µm and f_1 = 1.0*		
1	0.097	0.028	0.015
7	0.34	0.090	0.045
14	0.77	0.17	0.085
Caesium-137	*Assuming absorption type F, AMAD of 5 µm and f_1 = 1.0*		
1	0.13	0.12	0.21
7	0.21	0.18	0.29
14	0.31	0.22	0.30
Iridium-192	*Assuming absorption type F, AMAD of 5 µm and f_1 = 0.01*		
1	0.13	0.04	0.04
7	0.28	0.09	0.09
14	0.34	0.11	0.10

Table 5: Dose corresponding to a measurement equal to the detection limit for a PM11 detector and collimator assuming 'worst case' intake parameters

Time between intake and measurement (days)	Committed effective dose (mSv)		
	Age		
	1 year	10 years	20 years
Cobalt-60	*Values are the highest dose calculated for inhalation of aerosols with AMAD in the range 0.01–100 µm, and for inhalation and ingestion as intake routes. For inhalation, all 3 default ICRP absorption types are considered*		
1	70	36	38
7	410	170	170
14	960	390	380
Selenium-75	*Values are the highest dose calculated for inhalation of aerosols with AMAD in the range 0.01−100 µm, and for inhalation and ingestion as intake routes. For inhalation, only absorption type F is considered as no compounds have been assigned to other types in ICRP Publication 119 (ICRP, 2012)*		
1	2.2	1.0	0.67
7	2.9	1.2	0.84
14	3.4	1.4	0.97
Strontium-90/ yttrium-90	*Values are the highest dose calculated for inhalation of aerosols with AMAD in the range 0.01–100 µm, and for inhalation and ingestion as intake routes. For inhalation, all 3 default ICRP absorption types are considered*		
1	24,000	10,000	14,000
7	50,000	15,000	20,000
14	85,000	23,000	37,000
Iodine-131	*Values are the highest dose calculated for inhalation of aerosols with AMAD in the range 0.01−100 µm, and for inhalation and ingestion as intake routes. For inhalation, only absorption types F and M are considered as no compounds have been assigned to type S in ICRP Publication 119 (ICRP, 2012)*		
1	0.62	0.21	0.07
7	1.0	0.28	0.09
14	2.0	0.49	0.16
Caesium-137	*Values are the highest dose calculated for inhalation of aerosols with AMAD in the range 0.01−100 µm, and for inhalation and ingestion as intake routes. For inhalation, all 3 default ICRP absorption types are considered*		
1	8.4	4.8	4.5
7	23	11	8.0
14	46	17	12
Iridium-192	*Values are the highest dose calculated for inhalation of aerosols with AMAD in the range 0.01−100 µm, and for inhalation and ingestion as intake routes. For inhalation, all 3 default ICRP absorption types are considered*		
1	0.85	0.30	0.33
7	5.8	1.9	1.7
14	9.6	3.0	2.8

11 Discussion

Following an incident where activity is dispersed in the environment, the most important objective is to identify people who require medical assessment. A second objective is to quantify committed effective doses to find people who may benefit from decorporation therapy or might be included in any long-term follow-up study. The TMT Handbook (Rojas-Palma et al, 2009) states that people should have a medical assessment if the committed effective dose exceeds 200 mSv. It has been shown that people with predicted committed effective doses of this magnitude are unlikely to receive organ doses which exceed the threshold for tissue damage (Youngman et al, 2011). Thus identifying people who may receive a committed effective dose of 200 mSv will automatically identify people whose organ doses might exceed the damage thresholds. Guidance for intakes of radiocaesium (HPA, 2010) recommends that decorporation treatment using Prussian Blue be considered for people whose committed effective doses would exceed 30 mSv, and that significant benefits would be gained by providing this treatment for people with projected doses greater than 300 mSv.

The doses corresponding to a measurement at the detection limit presented in the tables in Section 10 show that when default intake parameters are assumed, internal contamination corresponding to doses of a few millisievert can be detected in people of all ages and for times between intake and measurement of up to 14 days. This is the case for all of the beta/gamma or gamma emitting radionuclides studied and is likely to be true for other radionuclides which emit at least 1 gamma ray of energy greater than 200 keV with high probability. These radionuclides include manganese-54, silver-110m, caesium-134, europium-152 and europium-154. For intakes of radiocaesium, the monitoring facility, described in this report, would be able to identify people who should be considered for treatment with Prussian Blue. For the beta emitting radionuclide strontium-90 in equilibrium with its short-lived decay progeny, yttrium-90, the dose corresponding to a measurement at the detection limit is much higher, at around 150 mSv for a time between intake and measurement of 14 days. However, even for this radionuclide, it would still be possible to identify people who require medical assessment.

Although not presented in this report, it was also shown that for alpha/gamma emitting radionuclides it was not possible to detect intakes in people corresponding to committed effective doses of less than 200 mSv (Youngman et al, 2011). For these radionuclides, a measurement at the detection limit corresponds to a dose of the order of several sievert. These monitoring facilities should not be employed for incidents where the only radionuclide released is an alpha emitter.

If worst case intake parameters are assumed, then it would be possible to identify people who require medical assessment for most beta/gamma and gamma emitting radionuclides but not cobalt-60 or the pure beta emitter strontium-90/yttrium-90. It would also still be possible to identify people aged greater than 1 year where treatment with Prussian Blue should be considered.

This discussion has so far assumed that only single radionuclides would be released, as is most probable for a deliberate release. For mixtures of radionuclides which include some beta/gamma or gamma emitters, then these facilities could be used to find those people who are most contaminated. If the proportions of different radionuclides in the mixture can be quantified, it would then be possible to calculate count rates which correspond to doses where medical assessment is needed. Caution is required with this approach as the dose can be

dominated by radionuclides which do not emit penetrating radiation. If the proportion of gamma emitting radionuclides is low, then these facilities may not be sensitive enough to detect people who require medical assessment.

It is estimated that for each detector system it would be possible to monitor 20 people in an hour, allowing time for positioning the person, moving the detector and recording the result.

It is recommended that people who have high levels of internal contamination are also measured on a system capable of spectrometry, such as described by Youngman (2002; 2008), so that measured radionuclide activities can be confirmed and to check for the presence of other gamma emitting radionuclides.

12 Conclusions

It has been shown that a PM11 detector based on a 51 mm by 51 mm sodium iodide detector used with a digital meter can be a useful tool in monitoring members of the public for internal contamination following an incident where radionuclides are dispersed in the environment. The monitoring facility described can be used to measure radionuclide activity in the whole body and also iodine-131 in the thyroid.

When default intake parameters are assumed, it has been shown that monitoring systems based on this type of detector are sensitive enough to identify people who require medical assessment with measurements made up to at least 14 days after the incident for releases of beta/gamma or gamma emitting radionuclides. They are also sensitive enough to detect people who would benefit from decorporation treatment for intakes of radiocaesium using Prussian Blue.

For incidents where mixtures of radionuclides are released that include a gamma emitter of energy greater than 200 keV and with high gamma radiation yield, this facility can be used to identify the most contaminated people for subsequent measurement using systems capable of spectrometry.

The throughput of this facility would be valuable for incidents where large numbers of people are likely to be contaminated.

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Appendix A Detailed Procedures

A1 Survey meter operation

1. Attach meter to detector using the cable provided
2. Attach collimator so that the end of the collimator is flush with the end of the detector
3. Switch the RAM DA-2000 on by pressing the ‘on/off’ button
4. Check if the battery warning icon is illuminated. If so, replace batteries before proceeding
5. Check that the detector number is displayed is given as ‘4’. If this is not the case, then do not proceed
6. Mute the speaker by pressing the ‘speaker’ button
7. Press the ‘units’ button twice so that the display changes from cps or cpm to ‘counts’ and a scale reading to 100 seconds appears
8. Position the detector as specified in Section 5 of the main text
9. Press the ‘count’ button and wait for approximately 20 seconds to elapse (use a clock or watch to estimate when 20 seconds has elapsed)
10. At the end of the count time press ‘count’ to stop the count
11. Press ‘count’ again and record the indicated count
12. Press ‘count’ again and the actual count time is displayed
13. Calculate the count rate in counts per second
14. Press ‘count’ again to make a new measurement

A2 Background determinations

For each detector position a separate background is needed. For background determinations, proceed as in Section A1 for a measurement but use someone known not be contaminated such as a member of the monitoring team. It is unnecessary to determine separate backgrounds for subjects of different ages.

Appendix B Report Forms

B1 Whole body survey report

Unique person code (or attach bar code):

Date of exposure: _____/_____/_____ Time of exposure: _____

Intake pathway (if known): Inhalation ☐ Ingestion ☐ Skin absorption ☐ Wound ☐

Person externally decontaminated: Yes ☐ No ☐

Date of measurement: ____/_____/_____ Time of measurement: _____

Results of measurement

Instrument type: _____ Model: _____ S/N _____

Average subject gross count rate (cps): _____

Average person background count rate (cps):_____

Net subject count rate (cps): _____

Activity (Bq): _____

Committed effective dose, if calculated (mSv): _____

Results of gamma-ray spectrometry measurement

Radionuclide	Measured value (Bq)	Committed effective dose (mSv), if calculated

Action levels (tick one option)

Activity above upper action level ☐

Activity between lower and upper action level ☐

Activity below lower action level ☐

Activity not detected ☐

Name: _____

Organisation: _____

Date: _____

B2 Thyroid survey report

Unique person code (or attach bar code):

Date of exposure: _____/_____/_____ Time of exposure: _____
Intake pathway (if known): Inhalation ☐ Ingestion ☐ Skin absorption ☐ Wound ☐

Stable iodine taken: Yes☐ No ☐
If Yes, time of administration (HH:MM) _____
Date of administration (dd/mm/yy) _____

Date of measurement: _____/_____/_____ Time of measurement: _____

Results of measurement

Instrument type: _____ Model: _____ S/N _____
Distance from neck to detector: 0 / 10 cm
Average environmental background count rate (cps): _____
Average gross subject thyroid count rate (cps): _____
Average body background count rate (cps): _____
Net subject thyroid count rate (cps): _____
Activity (Bq): _____
Committed effective dose, if calculated (mSv): _____

Results of gamma-ray spectrometry measurement

Radionuclide	Measured value (Bq)	Committed effective dose (mSv), if calculated

Action levels (tick one option)

Activity above upper action level ☐
Activity between lower and upper action level ☐
Activity below lower action level ☐
Activity not detected ☐

Name: _____
Organisation: _____
Date: _____