Practical Guidance on Thyroid Monitoring for Radioiodine Using Hand-held Instruments

M J Youngman

ABSTRACT

Following an incident involving release of radioactive iodine, it may well be necessary to monitor large numbers of people for internal contamination. In the case of iodine-125 (^{125}I), iodine-131 (^{131}I) and radioiodine releases from nuclear reactors (mixtures of ^{131}I and shorter lived iodine radionuclides) screening measurements can be done with simple scintillation probe based instruments held over the thyroid.

This guidance gives a procedure for monitoring of the thyroid using Mini Instruments type 44 and type 42 probes. Factors are given to convert measured count rates to activity in thyroid, dose to the thyroid and committed effective dose for intakes by inhalation. Measurements with these instruments are capable of detecting about 2 kBq of ^{131}I and 1 kBq of ^{125}I in the thyroid of an adult. For measurements made 24 hours after intake, these activities correspond to values of committed effective dose of 0.2 and 0.05 mSv for ^{131}I and ^{125}I respectively, assuming stable iodine has not been administered.

Centre for Radiation, Chemical and Environmental Hazards
Chilton, Didcot,
Oxfordshire OX11 0RQ

Approval: February 2013
Publication: February 2013
£15.00
ISBN 978-0-85951-729-4

EXECUTIVE SUMMARY

Following an incident involving the release of radioactive iodine, it may well be necessary to monitor large numbers of people for internal contamination. Accidental releases of radioiodine are possible in a variety of circumstances. For example intakes of iodine-125 (^{125}I) or iodine-131 (^{131}I) are possible during preparation of labelled pharmaceuticals at hospitals, or as a result of a release of ^{131}I from a nuclear reactor. ^{125}I and ^{131}I could also be used in an improvised radiological device (IRD, 'dirty bomb'). This guidance describes procedures for monitoring of the thyroid for radioiodine. It contains calibration factors to convert measured count rates, determined with a Mini Instruments type 42 or type 44 probe, to activity in thyroid. Factors are also given to convert count rates to thyroid dose and effective dose. Separate factors are provided for three separate intake scenarios, these are; intake by inhalation of iodine-125, intake by inhalation of iodine -131, and intake by inhalation of iodine-131 with other shorter lived iodine radionuclides which would be released from nuclear reactors.

This report contains guidance on the most suitable probe to use, which is dependent on the radionuclide(s) in the release. It also contains detailed instructions for carrying out monitoring of the thyroid. Calibration factors are given to convert measured count rates to activity in thyroid for children and adults. Factors are also given to convert measured count rate to committed effective dose and thyroid dose for three age groups and for up to 20 days between inhalation and monitoring. A report form is provided for recording the monitoring results for each person.

Providing stable iodine has not been administered, the methods described can be used to detect activities in the thyroid corresponding to committed effective doses of less than 10 mSv up to 20 days after intake.

CONTENTS

1 INTRODUCTION

Accidental intakes of radioiodine are possible in a variety of circumstances. For example intakes of iodine-125 (^{125}I) or iodine-131 (^{131}I) are possible during preparation of labelled pharmaceuticals at hospitals, or as a result of a release of ^{131}I from a nuclear reactor. ^{125}I and ^{131}I could also be used in an improvised radiological device (IRD, 'dirty bomb'). The half lives of ^{125}I and ^{131}I are 60 and 8.04 days, respectively. In the case of a reactor release, ^{131}I is likely be present together with shorter lived iodine radionuclides, ^{132}I (half-life 2.3 hours), ^{133}I (20.8 hours) and ^{135}I (6.6 hours). If however there is a delay after the reactor is shut down before the release, these shorter lived iodine radionuclides will have decayed.

These radionuclides are some of the easiest to monitor by external counting, because they emit relatively penetrating gamma rays and they concentrate predominantly in the thyroid. The thyroid is a small organ sited in the base of the neck, with little overlying tissue. As a result the detector can be placed close to the site where the radioiodine is concentrated.

This guidance covers measurements of ^{125}I, ^{131}I and mixtures of ^{131}I and short-lived radionuclides (that could be released from a nuclear reactor) in the thyroid gland. It is intended to be used principally for emergency monitoring, where large numbers of people may require screening. Those individuals who are found to have significant internal contamination would then be measured using more accurate techniques.

For emergency monitoring of radioiodine in the thyroid, it is simplest to use hand-held health physics instruments, as these are readily available and simple to operate. The disadvantage of these instruments is that the measurements are not particularly accurate or as sensitive as more sophisticated techniques. Instruments based on a sodium iodide crystal are best suited for measurements of radioiodine.

This guidance includes calibration factors for converting net thyroid count rate to activity (hereafter called calibration factors) and also conversion factors to calculate doses from net thyroid count rate (hereafter called dose conversion factors). The dose conversion factors could be used to calculate approximate individual doses for screening purposes, or to determine dose action levels in terms of a measured count rate. Two types of dose conversion factors are presented, to calculate both committed effective dose (E) and committed equivalent dose to the thyroid (hereafter called thyroid dose). The committed effective dose is the sum of the weighted equivalent doses in all the tissues and organs of the body. It takes account of the susceptibility of organs and tissues to radiation damage and accounts for continuing exposures expected to be received over a period of time (such as 50 or 70 years). Committed effective dose is used to measure the increase in long term risk of cancer. People who will receive higher committed effective doses might be selected for long-term health surveillance. Committed equivalent dose is the energy absorbed by the thyroid (weighted by a factor to allow for the different effectiveness of the various ionising radiations) and is used to assess the harm caused to the tissues of the thyroid. If a significant number of cells within tissues are damaged organ failure can result. Exposure of the thyroid can cause thyroid hormone deficiency (hypothyroidism) which although not fatal can produce a wide range

of health effects such as cold intolerance, weight gain, fatigue and depression which may require treatment.

Calibration factors and dose conversion factors in this guidance have been calculated for the Mini 900 Instrument with either a type 44 or type 42 probe (Thermo Electron Corporation, Reading, UK) which are in common use in the UK. Advice on the most suitable probe to use for a particular radioiodine nuclide is given in this guidance. The dose conversion factors in this guidance were calculated using the ERIDAS (Emergency Response Internal Dose Assessment Software) program (Youngman et al., 2007).

2 SCOPE

This guidance is only applicable when:

- Intake is by inhalation (which would be expected soon after a reactor accident or a dirty bomb incident), although the measurement procedure can be used to determine activity in thyroid for other modes of intake.
- The radionuclide inhaled is ^{131}I, ^{125}I or a mixture of ^{131}I and shorter lived iodine radionuclides released from a nuclear reactor.
- Intake is acute (i.e. occurs for no more than about 2 hours), although the measurement procedure can be used to determine activity in thyroid for chronic intakes.
- Measurements are made up to 20 days after the intake (For measurements made after 20 days the ERIDAS program can be used to calculate dose).
- Measurements are made using Mini Instruments type 44 or type 42 scintillation probes.

This guidance can be used if stable iodine has been taken by the subject providing it was not taken before the intake occurred.

3 MONITORING METHOD

3.1 Monitoring location

Monitoring of people for internal and external contamination would normally be carried out at a temporary Radiation Monitoring Unit, set up close to the incident. Information on setting up and running a radiation monitoring unit has been published by HPA

(Thompson et. al., 2011). The most important points are all follows. The RMU should be located in a covered area large enough to deal with the demand. There must be adequate separation of people waiting for monitoring, being monitored, and awaiting transfer for further assessment. It may be necessary to monitor people for external contamination as well as internal contamination. If it is possible that external contamination could be present on people then decontamination facilities should be made available.

The monitoring should be carried out at a location where the levels of natural background radiation are not unusually high, and where levels have not been significantly enhanced by contamination from the incident.

The monitoring area in particular should be kept free of contamination. Chairs and floors should be covered so that they can be easily decontaminated.

The TMT Handbook (Rojas-Palma et. al., 2009) and a report by the US Center for Disease Control (CDC, 2007) contain additional information on monitoring of people following a radiological incident.

3.2 Monitoring time after intake

As ^{131}I has a half-live of 8 days it is important to begin monitoring soon after any suspected intake, ideally within a few days. ^{125}I has a longer half-live of 60 days and so is present in the thyroid for longer. Dose conversion factors are provided for monitoring times from 1 hour after intake. However, as it takes time for radioiodine to reach the thyroid, monitoring should not be started until at least 8 hours after the intake. Radioiodine that has reached the thyroid is retained with a half-time of approximately 80 days in adults.

3.3 Instrument selection

This guidance covers measurements with sodium iodide (NaI) based scintillation probes of types 44A, 44B, 42A and 42B. These probes are used in conjunction with a rate-meter or sometimes a scalar. If measurements are made with a scalar, the measured count rate should be divided by the count time, to give counts per second.

Type 42 probes are designed for detection of X-rays and therefore have a crystal which is only 1 mm thick. The 42A has a 0.05 mm thick aluminium window and the 42B a 0.25 thick beryllium window. For detection of ^{125}I and ^{131}I there is essentially no difference between probes, and therefore both are treated together and are referred to in this guidance as type 42.

Type 44 probes (figure 1) are designed to detect higher energy gamma emitters and therefore have a thicker (2.5 mm) crystal than the type 42 probes. The crystal is also larger in diameter which reduces the error produced from any misalignment of the

detector. Type 44 probes also have type A and B versions with aluminium and beryllium windows respectively. For detection of ^{131}I there is essentially no difference between the characteristics of type A and B, and therefore both are treated together and are referred to as type 44.

All of these instruments are small enough to be held close to the neck, and are light enough to be hand-held for long periods.

Figure 1 Mini 900 instrument with a type 44 probe

3.3.1 Detection of ^{125}I

Both type 44 and 42 probes are suitable for monitoring of ^{125}I. The type A probes (aluminium window) should be used in preference to the type Bs as the window is more robust and the risk from using beryllium is eliminated.

3.3.2 Detection of ^{131}I and mixtures of ^{131}I and short-lived iodine radionuclides

Type 44 probes are suitable for monitoring of ^{131}I and mixtures of ^{131}I with short-lived iodine radionuclides. Again, the A versions should be used in preference to the beryllium windowed instruments. The use of type 42 probes is not recommended and therefore conversion factors are not given in this guidance. Any end-caps designed to protect the probes should be removed before measurements commence.

3.4 Subject to detector distance

Measurements can be made with the probe as close as possible to the subject's neck without touching the skin (this is described as 'close' elsewhere in this guidance) or at a distance of 10 cm. Having the detector close to the neck maximises the measurement

sensitivity which would be needed for most screening measurements. A distance of 10 cm should be used if the count rates with the detector held close to the neck are high enough to prevent accurate reading of the analogue scale on the ratemeter.

3.5 Detector positioning

The thyroid gland lies in the front of the lower neck in a position just below the Adam's apple and above the line of the clavicles. It is made up of two lobes, each about the size of a plum cut in half, lying on either side of the trachea. The probe must be held so that the bottom edge is just above the line of the clavicles (figure 2).

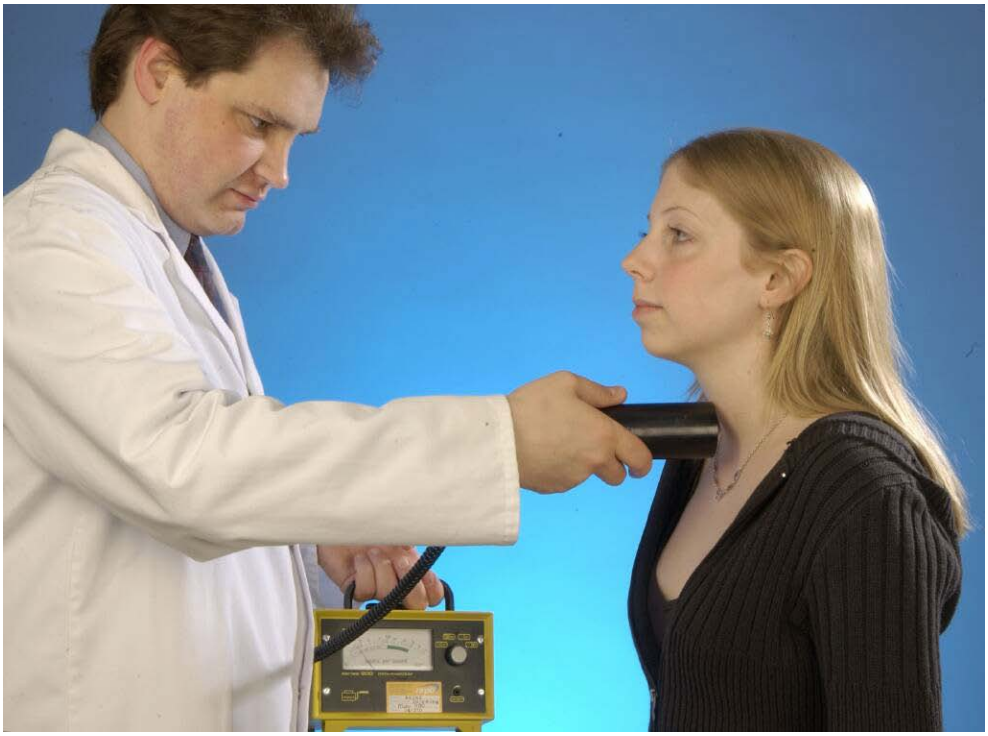

Figure 2 Measuring a subject's thyroid

3.6 Stable iodine

The administration of stable iodine is a widely accepted countermeasure to mitigate the effects of a release of radioiodine. The stable iodine is used to reduce uptake of radioactive iodine by the thyroid gland. It is possible that people having thyroid measurements will have received stable iodine so that uptake of radioiodine by the thyroid has been partially or almost totally blocked. It is important to know if the subject has received stable iodine, and if so the time it was taken.

If stable iodine was administered before the intake occurred, then blocking will be almost 100% effective. In this case it is unlikely that any radioiodine will be detected in the thyroid. The measurement can go ahead, and if radioiodine is detected the tables in

this guidance can be used to calculate activity in the thyroid but can not be used to calculate dose.

If stable iodine was taken more than 12 hours after the intake then it can be assumed to have been ineffective (Kovari and Morrey, 1994) and the dose should be calculated assuming stable iodine was not administered.

3.7 Screening

The techniques described in this guidance are well suited for screening of large numbers of people. Action levels may be set in terms of counts per second corresponding to set levels of dose. The tables in this guidance can be used to calculate background subtracted counts per second values which can be compared with measurements to allow rapid sorting of people. These action levels would need to be set according to the particular circumstances of an incident. More information on action levels can be found in the TMT Handbook in chapter F, section 3.1 (Rojas-Palma et.al., 2009).

4 MEASUREMENT PROCEDURE

4.1 Procedure

Staff carrying out monitoring should wear appropriate Personal Protective Equipment (PPE). A list of suitable PPE and other safety precautions are given in the TMT Handbook (Rojas-Palma et.al., 2009). It is recommended that monitoring staff wear a personal dosimeter (film badge or thermoluminescent dosimeter (TLD)) and be monitored for thyroid contamination at the end of each day. The monitoring process is similar to that described by the Canadian Nuclear Safety Commission (2008).

Before monitoring commences the following activities must be completed:

- Set up the monitoring area in an area of low radiation background, if possible. It is also important that the background should be stable.
- Check that the monitor to be used has undergone performance checks within the last year (i.e. as specified in national regulation (HSE, 1999)).
- Check the battery level on all monitors to be used (and at regular intervals).
- If a portable radioactive check source is available, move the source closer to and further away from the probe to ensure the registered count rate increases and decreases accordingly.
- Cover the end of the probe with cling-film and replace if contamination of the monitor is suspected.

- Ensure that there is 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 to ensure their presence will not affect measurement of the child.

While being measured the subject should be seated or standing. If the subject is laying-down the amount of overlying tissue increases which will result in the activity being underestimated.

For each subject, a subject questionnaire should be completed if this has not already been done. Information recorded on the subject questionnaire should include personal information, contact details and location at the time of the incident. An example subject questionnaire is given in annex 3 of the TMT Handbook (Rojas-Palma et.al., 2009). All information connected with thyroid measurements should be recorded, an example record is given in annex A of this guidance.

Figure 3 gives details of the measurement procedure to be used. The following count rates should be measured and recorded:

1. Average environmental background count rate

This is determined by holding the probe in the monitoring area, but not close to any people or objects, and recording the average reading by observing for about 15 seconds. This measurement should be repeated as often as possible.

2. Average thyroid count rate

With the subject standing or sitting, measure the count rate over the thyroid with the probe close to the skin but not touching (see figure 2).

3. Average body background count rate

If the average thyroid count rate is greater than or equal to twice the average environmental background count rate, measure the average body background count rate. With the subject standing or sitting measure the count rate on the lower thigh, using the same instrument. The probe to skin distance should be the same as used for the thyroid measurement. If the average thyroid count rate is not greater than or equal to twice the average body background count rate then radioiodine has not been detected in the thyroid. If the average thyroid count rate is greater than or equal to twice the average body background count rate then radioiodine has been detected and the subject net thyroid count rate is equal to the thyroid count rate minus the average body background count rate.

This procedure is shown in the flow diagram (figure 3).

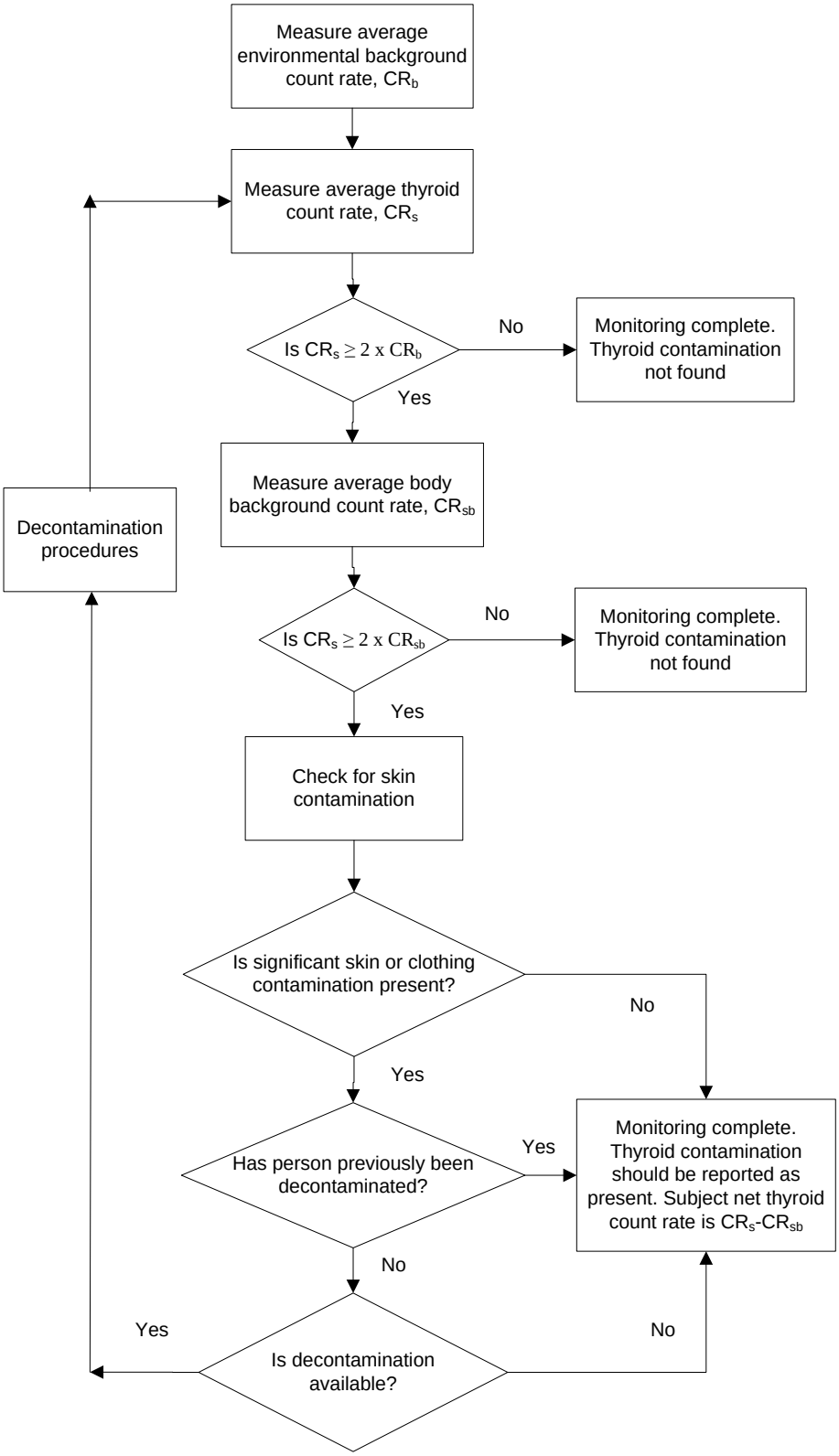

Figure 3 Flow diagram showing thyroid monitoring procedure

4.2 Skin contamination

Any contamination on the subject's skin or clothing in the vicinity of the neck will contribute to the subject's thyroid count rate. The presence of contamination on the skin and clothing can be detected using a beta sensitive instrument. Detailed procedures are beyond the scope of this guidance but are given in the TMT Handbook (Rojas-Palma et.al., 2009). The technique of subtracting the average body background count rate from the thyroid count will help correct measurements made in the presence of skin contamination. If skin or clothing contamination is suspected and decontamination facilities are available, the person should be decontaminated and the thyroid measurement made after decontamination. If decontamination facilities are not available, then the thyroid measurement should proceed and the possible presence of surface contamination should be recorded.

4.3 Calculating and recording results

For each subject the results of iodine in thyroid monitoring should be recorded. An example form is included as annex A. Other forms for recording results can be found in the TMT Handbook (Rojas-Palma et.al., 2009). The net thyroid count rate should be compared with any action levels which have been set (see section 3.7).

4.3.1 Calculation of activity

Activity in the thyroid should only be calculated if thyroid contamination has been positively identified. The subject net thyroid count rate should be calculated as shown in Figure 3.

To calculate activity (Bq) multiply the net thyroid count rate by the values in the tables specified in Table 1.

To calculate a minimum detectable activity (where radioiodine has not been detected) multiply the factor from Tables 4 to 7 (as appropriate) by twice the average environmental background count rate CR_b.

Administration of stable iodine does not affect the calculation of activity of radioiodine in the thyroid.

Table 1 Tables of calibration factors to convert net thyroid count rate to activity in the thyroid

Scenario	Probe Type	
	44	42
^{131}I only	Table 4	NA
^{125}I only	Table 5	Table 6
Reactor release < 12 hours between reactor shutdown and release	Table 7	NA
Reactor release > 12 hours between reactor shutdown and release	Table 4	NA

NA Not applicable

Calibration factors are given in tables 4-7 for both probe to subject distances and for adults and children. Factors are given for two age groups as the amount of tissue overlying the thyroid increases with age. Note that for a reactor accident the tables are used to calculate the activity of ^{131}I in the thyroid, as this is the most radiologically significant radionuclide. For reactor accidents, the time between reactor shutdown and intake is important as the contribution from ^{131}I to the total count rate changes. For times intermediate between those given in table 7 the next highest time should be used to ensure activities are not underestimated.

4.3.2 Calculation of dose

Doses should only be calculated if thyroid contamination has been positively identified. The subject net thyroid count rate should be calculated as shown in Figure 3.

To calculate a minimum detectable dose (where radioiodine has not been detected) the dose conversion factors should be multiplied by twice the average environmental background count rate CR_b.

Stable iodine not taken

To calculate committed effective dose (E) the subject net thyroid count rate should be multiplied by the values in the tables referenced in Table 2. Dose conversion factors are given in these tables for both probe to subject distances and for three age groups. For times intervals between intake and monitoring which are intermediate between the values given in the tables the longer interval should be used.

The thyroid dose can be obtained by dividing the calculated value for effective dose by the tissue weighting factor for the thyroid (i.e. 0.05).

Table 2 Tables of factors to convert net thyroid count rate to dose when no stable iodine is taken

Scenario	Probe type	
	44	42
^{131}I only	Table 8	NA
^{125}I only	Table 9	Table 10
Reactor release < 12 hours between reactor shutdown and release	Table 11	NA
Reactor release > 12 hours between reactor shutdown and release	Table 8	NA

NA Not applicable

Stable iodine taken

If stable iodine has been administered, to calculate committed effective dose the subject net thyroid count rate should be multiplied by the values in the tables referenced in Table 3. Dose conversion factors are given in these tables for both probe to subject distances and for three age groups. For times intervals between intake and monitoring which are intermediate between the values given in the tables the longer interval should be used.

If stable iodine was administered later than 12 hours after intake, then it should be assumed it was not taken, and the tables referenced in table 2 should be used to calculate dose.

An approximate thyroid dose can be obtained by dividing the calculated value for effective dose by the tissue weighting factor for the thyroid (i.e. 0.05).

Table 3 Tables of factors to convert net thyroid count rate to dose when stable iodine is taken

Scenario	Probe Type	
	44	42
^{131}I only	Table 12	NA
^{125}I only	Table 13	Table 14
Reactor release < 12 hours between reactor shutdown and release	Table 15	NA
Reactor release > 12 hours between reactor shutdown and release	Table 12	NA

NA Not applicable

4.4 Measurement uncertainties

The procedures in this guidance use small detectors close to the thyroid, which can lead to uncertainties in the determination of activity in the thyroid of about a factor of 2 (Canadian Nuclear Safety Commission (2008). This is mainly due to errors in detector

placement and uncertainty of thyroid depth. Using a 10 cm neck to detector distance will decrease the error due to uncertainty in thyroid depth but introduces an extra uncertainty for the error in maintaining the correct neck to detector distance. It is likely that the overall uncertainty for measurements at a distance of 10 cm is also about a factor of 2. These uncertainties are specified at the 95% confidence level.

5 ACTIVITY CALIBRATION FACTORS

Table 4 Calibration factors for determining activity of ^{131}I, Type 44 Probe

	Activity Conversion Factor, Bq per cps	
Age	Monitoring Distance - close	Monitoring Distance – 10 cm
< 18 years	110	710
Adult	190	1000

Note: This table should also be used for reactor incidents where the time from reactor shutdown to release is greater than 12 hours.

Table 5 Calibration factors for determining activity of ^{125}I, Type 44 Probe

	Activity Conversion Factor, Bq per cps	
Age	Monitoring Distance - close	Monitoring Distance – 10 cm
< 18 years	40	260
Adult	120	560

Table 6 Calibration factors for determining activity of ^{125}I, Type 42 Probe

	Activity Conversion Factor, Bq per cps	
Age	Monitoring Distance - close	Monitoring Distance – 10 cm
< 18 years	130	670
Adult	320	1300

Table 7 Calibration factors for determining activity of ^{131}I following a reactor release, 0-12 hours between reactor shutdown and intake, Type 44 probe

Time between intake and monitoring	Activity Conversion Factor (Bq ^{131}I per cps)			
	Monitoring Distance – close		Monitoring Distance – 10 cm	
Age	< 18 years	Adult	< 18 years	Adult
2 hours	64	114	416	593
4 hours	67	119	436	619
6 hours	70	123	455	640
8 hours	72	127	468	660
12 hours	76	135	494	702
1 day	86	151	559	785
2 days	97	172	631	894
4 days	108	190	702	988
5 days and over	110	190	710	1000

6 DOSE CONVERSION FACTORS

6.1 No stable iodine

Table 8 Conversion factors for determining committed effective dose for measurements of ^{131}I, type 44 probe, no stable iodine taken

Time between intake and monitoring	Dose Conversion Factor (mSv per cps)					
	Monitoring Distance – close			Monitoring Distance – 10 cm		
	Less than 5 years	5 to 10 years	10 years and over	Less than 5 years	5 to 10 years	10 years and over
1 hour	0.86	0.49	0.25	5.5	3.2	1.6
2 hours	0.40	0.22	0.11	2.6	1.4	0.71
3 hours	0.27	0.15	0.076	1.7	0.96	0.49
4 hours	0.21	0.11	0.058	1.4	0.71	0.37
6 hours	0.15	0.083	0.042	0.96	0.53	0.27
8 hours	0.12	0.068	0.035	0.77	0.44	0.23
12 hours	0.10	0.055	0.028	0.64	0.35	0.18
1 day	0.09	0.046	0.023	0.58	0.30	0.15
4 days	0.12	0.060	0.029	0.77	0.39	0.19
6 days	0.16	0.075	0.035	1.0	0.48	0.23
8 days	0.20	0.094	0.043	1.3	0.60	0.28
10 days	0.27	0.12	0.052	1.7	0.75	0.33
12 days	0.35	0.15	0.063	2.3	0.93	0.41
14 days	0.45	0.18	0.076	2.9	1.2	0.49
16 days	0.59	0.22	0.092	3.8	1.4	0.59
18 days	0.76	0.28	0.12	4.9	1.8	0.77
20 days	0.99	0.35	0.14	6.4	2.3	0.90

Notes: To obtain thyroid doses these values should be multiplied by a factor of 20.

This table should also be used where the time from reactor shutdown to intake is greater than 12 hours.

Table 9 Conversion factors for determining committed effective dose for measurements of ^{125}I, type 44 probe, no stable iodine taken

Time between intake and monitoring	Dose Conversion Factor (mSv per cps)					
	Monitoring Distance - close			Monitoring Distance – 10 cm		
	Less than 5 years	5 to 10 years	10 years and over	Less than 5 years	5 to 10 years	10 years and over
1 hour	0.088	0.072	0.054	0.54	0.44	0.33
2 hours	0.041	0.032	0.022	0.25	0.20	0.14
3 hours	0.028	0.022	0.016	0.17	0.14	0.098
4 hours	0.021	0.017	0.013	0.13	0.10	0.080
6 hours	0.015	0.012	0.0091	0.092	0.074	0.056
8 hours	0.013	0.0098	0.0074	0.080	0.060	0.046
12 hours	0.010	0.0078	0.0059	0.062	0.048	0.036
1 day	0.0082	0.0063	0.0047	0.050	0.039	0.029
4 days	0.0092	0.0066	0.0047	0.057	0.041	0.029
6 days	0.010	0.0071	0.0049	0.062	0.044	0.030
8 days	0.012	0.0076	0.0052	0.072	0.047	0.032
10 days	0.013	0.0082	0.0054	0.081	0.050	0.033
12 days	0.015	0.0088	0.0056	0.090	0.054	0.034
14 days	0.016	0.0094	0.0059	0.10	0.058	0.036
16 days	0.018	0.010	0.0061	0.11	0.062	0.038
18 days	0.021	0.011	0.0064	0.13	0.068	0.039
20 days	0.023	0.011	0.0066	0.14	0.068	0.041

Note: To obtain thyroid doses these values should be multiplied by a factor of 20.

Table 10 Conversion factors for determining committed effective dose for measurements of ^{125}I, type 42 probe, no stable iodine taken

Time between intake and monitoring	Dose Conversion Factor (mSv per cps)					
	Monitoring Distance - close			Monitoring Distance – 10 cm		
	Less than 5 years	5 to 10 years	10 years and over	Less than 5 years	5 to 10 years	10 years and over
1 hour	0.26	0.22	0.17	1.4	1.2	0.87
2 hours	0.13	0.099	0.075	0.69	0.52	0.40
3 hours	0.084	0.066	0.050	0.44	0.35	0.26
4 hours	0.064	0.051	0.038	0.34	0.27	0.20
6 hours	0.046	0.036	0.028	0.24	0.19	0.15
8 hours	0.038	0.030	0.023	0.20	0.16	0.12
12 hours	0.031	0.024	0.018	0.16	0.13	0.095
1 day	0.025	0.019	0.014	0.13	0.10	0.074
4 days	0.028	0.020	0.014	0.15	0.11	0.074
6 days	0.032	0.022	0.015	0.17	0.12	0.079
8 days	0.035	0.023	0.016	0.18	0.12	0.084
10 days	0.040	0.025	0.016	0.21	0.13	0.084
12 days	0.045	0.027	0.017	0.24	0.14	0.090

14 days	0.050	0.028	0.018	0.26	0.15	0.095
16 days	0.055	0.030	0.019	0.29	0.16	0.10
18 days	0.063	0.033	0.019	0.33	0.17	0.10
20 days	0.070	0.035	0.020	0.37	0.18	0.11

Notes: To obtain thyroid doses these values should be multiplied by a factor of 20.

Table 11 Conversion factors for determining committed effective dose for measurements of ^{131}I, following a reactor release, 0-12 hours between reactor shutdown and intake, type 44 probe, no stable iodine taken

Time between intake and monitoring	Dose Conversion Factor (mSv per cps)					
	Monitoring Distance - close			Monitoring Distance – 10 cm		
	Less than 5 years	5 to 10 years	10 years and over	Less than 5 years	5 to 10 years	10 years and over
1 hour	0.59	0.32	0.16	3.8	2.0	1.0
2 hours	0.29	0.15	0.076	1.9	0.96	0.49
3 hours	0.20	0.11	0.053	1.3	0.70	0.34
4 hours	0.16	0.075	0.042	1.0	0.48	0.27
6 hours	0.13	0.065	0.032	0.83	0.42	0.21
8 hours	0.11	0.057	0.028	0.70	0.37	0.18
12 hours	0.095	0.049	0.024	0.61	0.31	0.15
1 day	0.094	0.048	0.024	0.60	0.31	0.15
4 days	0.17	0.083	0.039	1.1	0.53	0.25
6 days	0.23	0.11	0.049	1.5	0.69	0.31
8 days	0.31	0.14	0.059	2.0	0.90	0.38
10 days	0.40	0.17	0.072	2.6	1.1	0.46
12 days	0.52	0.21	0.087	3.3	1.3	0.56
14 days	0.68	0.26	0.11	4.4	1.7	0.68
16 days	0.88	0.32	0.13	5.6	2.0	0.82
18 days	1.2	0.40	0.16	7.4	2.5	0.99
20 days	1.5	0.50	0.19	9.7	3.2	1.2

Notes: To obtain thyroid doses these values should be multiplied by a factor of 20.

For times between reactor shutdown and intake which exceed 12 hours then the values in Table 8 should be used.

6.2 Stable iodine administered

Table 12 Conversion factors for determining committed effective dose for measurements of ^{131}I, type 44 probe, stable iodine taken

Time between intake and monitoring	Dose Conversion Factor (mSv per cps)					
	Monitoring Distance - close			Monitoring Distance – 10 cm		
	Less than 5 years	5 to 10 years	10 years and over	Less than 5 years	5 to 10 years	10 years and over
<1 day	0.1	0.051	0.03	0.65	0.33	0.19
>1 day	Use values assuming stable iodine has not been administered					

Table 13 Conversion factors for determining committed effective dose for measurements of ^{125}I, type 44 probe, stable iodine taken

Time between intake and monitoring	Dose Conversion Factor (mSv per cps)					
	Monitoring Distance - close			Monitoring Distance – 10 cm		
	Less than 5 years	5 to 10 years	10 years and over	Less than 5 years	5 to 10 years	10 years and over
< 1 day	0.0062	0.0079	0.004	0.040	0.051	0.026
>1 day	Use values assuming stable iodine has not been administered					

Table 14 Conversion factors for determining committed effective dose for measurements of ^{125}I, type 42 probe, stable iodine taken

Time between intake and monitoring	Dose Conversion Factor (mSv per cps)					
	Monitoring Distance - close			Monitoring Distance – 10 cm		
	Less than 5 years	5 to 10 years	10 years and over	Less than 5 years	5 to 10 years	10 years and over
<1 day	0.020	0.026	0.013	0.110	0.140	0.071
> 1 day	Use values assuming stable iodine has not been administered					

Table 15 Conversion factors for determining committed effective dose for measurements of ^{131}I, following a reactor release, 0-12 hours between reactor shutdown and intake, type 44 probe, stable iodine taken

Time between intake and monitoring	Dose Conversion Factor (mSv per cps)					
	Monitoring Distance - close			Monitoring Distance – 10 cm		
	Less than 5 years	5 to 10 years	10 years and over	Less than 5 years	5 to 10 years	10 years and over
1 hour	0.071	0.039	0.021	0.462	0.254	0.137
2 hours	0.073	0.040	0.022	0.475	0.260	0.143
3 hours	0.075	0.041	0.022	0.488	0.267	0.143
4 hours	0.077	0.042	0.023	0.501	0.273	0.150
6 hours	0.081	0.044	0.024	0.527	0.286	0.156
8 hours	0.085	0.046	0.025	0.553	0.299	0.163
12 hours	0.092	0.049	0.026	0.598	0.319	0.169
1 day	0.110	0.059	0.031	0.715	0.384	0.202
2 days	0.150	0.075	0.039	0.975	0.488	0.254
4 days	0.210	0.100	0.053	1.365	0.650	0.345
6 days	0.300	0.140	0.066	1.950	0.910	0.429
8 days	0.410	0.170	0.081	2.665	1.105	0.527
10 days	0.550	0.220	0.098	3.575	1.430	0.637
12 days	0.740	0.270	0.120	4.810	1.755	0.780
14 days	0.990	0.350	0.150	6.435	2.275	0.975
16 days	1.300	0.440	0.180	8.450	2.860	1.170
18 days	1.800	0.550	0.220	11.700	3.575	1.430
20 days	2.400	0.690	0.260	15.600	4.485	1.690

7 ACKNOWLEDGEMENTS

The author wishes to thank J R H Smith and M Bracher for calibration of the instruments, and K Davies and J Marsh for development of the ERIDAS code which was used to calculate the dose conversion factors.

8 REFERENCES

Canadian Nuclear Safety Commission (2008). Thyroid Screening for Radioiodine. Regulatory Document RD-58. http://nuclearsafety.gc.ca/pubs_catalogue/uploads/RD-58_pdf_e.pdf

CDC (2007). Population monitoring in radiation emergencies: A guide for state and local public health planners. US Center for Disease Control and Prevention. http://emergency.cdc.gov/radiation/pdf/population-monitoring-guide.pdf

HSE (1999). The Ionising Radiations Regulations. Statutory Instruments 1999 No. 3232 http://www.hse.gov.uk/radiation/ionising/legalbase.htm

Kovari M and Morrey M (1994). The effectiveness of iodine prophylaxis when delayed: implications for emergency planning. *J. Radiol. Prot.* **14** 345

Rojas-Palma C, Liland A, Naess Jerstad A, Etherington G, Perez M. and Rahola T (2009). TMT Handbook: Triage, monitoring and treatment of people exposed to ionising radiation following a malevolent act. ISBN 978-82-90362-27-5. www.tmthandbook.org.

Thompson N J, Youngman M J, Moody J, McColl N P, Cox D R, Astbury J, Webb S and Prosser S L (2011). Radiation Monitoring Units: Planning and Operational Guidance. HPA-CRCE-017. http://www.hpa.org.uk/Publications/Radiation/CRCEScientificAndTechnicalReportSeries/HPACRCE017/

Youngman MJ, Davis KE, Etherington G and Marsh JW (2007). ERIDAS, A computer program for rapid calculation of doses from measurements of people in an emergency. *Rad Prot Dos* **127**, (1-4), 374-377.

APPENDIX A Record of iodine in thyroid monitoring with a hand-held probe

Unique Person Code[1] (or attach bar code):

Age: _____

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

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

Was stable iodine taken?: . Yes ☐ . No ☐
If Yes,
Date of administration (dd/mm/yy): ____/____/____
Time of administration (HH:MM): _____

Date of measurement (dd/mm/yy) : ____/____/____

Time of measurement (HH:MM): _____

Probe type used: 44 / 42
Distance from neck to detector: close / 10 cm

Average environmental background count rate, CR_b (cps): _____
Average gross subject thyroid count rate, CR_s (cps): _____
Average body background count rate, CR_{sb} (cps): _____
Net subject thyroid count rate (cps): _____

Radionuclide: I-125 / I-131/ I-131 + short lived iodine radionuclides
Activity (Bq): _____

Committed effective dose, if calculated (mSv): _____

Above Upper Action Level[2]? Yes ☐. No ☐
Above Lower Action Level[2] ? Yes ☐. No ☐

[1] The unique person code should be copied from the 'Subject Questionnaire'. If this has not been assigned then a unique code should be added and a separate record of the person's name and contact details should be kept.
[2] Upper and Lower Action Levels are described in the TMT Handbook (Rojas-Palma et.al.,2009)

APPENDIX B Assumptions used in the calculation of the conversion factors

1 The thyroid depths below the skin are 0.5 cm for children (<18 years) and 2.4 cm for adults. These depths are in reasonable agreement with the values recommended by ICRP (ICRP,1975).

2 Stable iodine is not effective if administered more than 10 hours after the intake.

3 Stable iodine was not administered before intake

4 The presence of extrathyroidal radioiodine does not make a significant contribution to count rate measured at the thyroid

5 The presence of skin or clothing contamination does not make a significant contribution to count rate measured at the thyroid.

6 For reactor releases, ^{132}Te is not released. If ^{132}Te was released then the activities and doses calculated using this guidance would be overestimated. If dose calculations are done using ERIDAS the operator can select that ^{132}Te was released. This effectively increases the half-life of ^{132}I so that less of the measured count rate is due to ^{131}I which is the most important radionuclide in terms of dose.

7 In the case of a nuclear reactor where mixtures of short-lived radionuclides (some with a half-life much less than one day) could be produced, it is not possible to obtain standardised solutions for calibration purposes. For these iodine radionuclides (^{132}I, ^{133}I and ^{135}I) calibration factors were obtained by multiplying the gamma-emission probabilities for each photon emitted by the percentage detection efficiency values taken from the Mini Instruments Series 900 Scintillation Mini-Monitor Manual (Morgan Electronics Division, Issue 2, 1986). These are then summed to give a value which represents the response of the probe. This process is repeated for ^{131}I and the values relative to ^{131}I are used to calculate calibration factors for each short-lived iodine radionuclide.

APPENDIX C Efficiency calibration procedures

The efficiency calibrations were made by measuring the response of the Mini Instruments type 42 and 44 probes to certificated solutions of ^{125}I and ^{131}I in a thyroid/neck phantom. This phantom consists of a 13.7 cm long muscle equivalent resin cylinder with a diameter of 12.5 cm. The phantom has three pairs of holes into which are inserted polythene tubes containing the ^{131}I or ^{125}I standard solution. These pairs of holes are used to represent different anterior thyroid depths. In this study the deepest pair of holes was not used.

The calibration accuracy depends to a large extent on how well the calibration phantom matches the subject with regard to thyroid depth, mass and shape. Table 16 compares the dimensions of the neck/thyroid phantom used for this study with values for an adult.

Table 16 Comparison of the phantom used to determine activity conversion factors with an adult person

Parameter	Actual (ICRP, 1975)	Calibration phantom
Overlying tissue thickness	0.4 – 2 cm	0.6, 2.6 and 4.2 cm
Thyroid Volume	20 cm^3	20 cm^3
Overall width	6 – 10 cm	5.5 cm
Transverse diameter (each lobe)	2 – 4 cm	1.7 cm
Vertical Diameter (each lobe)	5 – 8 cm	4.5 cm
Anteroposterior diameter	1 – 2.5 cm	1.5 cm
Isthmus transverse diameter	2 cm	Not represented
Isthmus vertical diameter	2 cm	Not represented
Isthmus anteroposterior diameter	0.2 – 0.6 cm	Not represented

Table 16 shows the phantom has similar dimensions to the anatomical dimensions of an adult, in particular the mass and overall size are in reasonable agreement. The calibration phantom does not have an isthmus but this represents only a small proportion of the total thyroid mass.

Reference

ICRP Publication 23 (1975) Report of the Task Group on Reference Man. Annals of the ICRP **23**.