Routine Internal Dosimetry Monitoring And Assessment: The Practical Application Of International Standards And Guidance

G. A. Roberts[1]; R. K. Bull[1]; D Spencer[2]
[1]Nuvia ltd, 351 Harwell Oxford, UK
[2]Nuvia ltd, D1310, Dounreay, Thurso, UK

Abstract

The monitoring and assessment of intakes of radionuclides is a complex process: a variety of methods have been developed. Recently, considerable effort has been put into establishing more definitive guidelines and standards, with the aim of 'harmonising' the methods. Recent publications of specific relevance are the ISO International Standard on *Monitoring of Workers Occupationally Exposed to a Risk of Internal Contamination with Radioactive Material*, and *Dose assessment for the monitoring of workers for internal radiation exposure*[1]; and the *IDEAS* project and guidelines[2]. These publications have sought to define some basic principles, objectives and methods; however, they still require to be incorporated into working procedures and applied in practice. The Radiation Dosimetry Department (RDD) of Nuvia is engaged in developing such procedures, and reviewing the practical challenges of applying them operationally. This paper reviews our experience, focussing on two of the main practical challenges.

1. When Should Routine Internal Monitoring Programmes be Implemented?

The ISO International Standard on Monitoring of Workers Occupationally Exposed to a Risk of Internal Contamination with Radioactive Material[1] (ISO 20553:2006) was published in 2006. This document offers guidance for the decision whether a monitoring programme is required and how it should be designed. The guidance for the design of monitoring programmes is well defined with detailed and objective criteria: e.g. specified monitoring methods and sampling frequencies. However, the guidance for when a programme is required in the first place is more subjective, this is summarised in Table 1 (reproduced from ISO 20553).

Table 1. Need for monitoring programmes according to the exposure situation

Type of monitoring required	Normative	Recommended Level
Workplace monitoring (e.g. workplace air samples)	If the worker is occupationally exposed and the assessed dose contribution from intakes of radionuclides is likely to be significant	If the likely annual committed effective dose exceeds 1 mSv
Individual monitoring (e.g. in-vivo monitoring, excreta sampling, personal air samples)	If the worker can be exposed to more than 30% of the dose limit by internal exposure	If the likely annual total dose exceeds 6 mSv

The difficulty with this guidance is that it requires a degree of judgement when applying phrases such as "…likely to be significant…" or "…can be exposed …" to prospective doses in practical situations; this problem is exacerbated for new operations for which there is no relevant past experience to aid the judgement. It is noted that similar semantics are employed in other sources of international and national recommendations and guidance[3][4][5][6]. As a dosimetry service we would seek to replace such semantics with more objective and quantifiable values, and preferably the results of measurement.

Several mathematical algorithms have been published[7][8][9][10] which relate a source term and various protection factors (for containment, physical form etc) to a prospective estimate of dose: i.e. a quantified risk estimate. A previous review[11] tested the response of these algorithms to a simple exposure situation of a known quantity of plutonium being processed in a fume hood. The results of this review are summarised in Table 2. The results are expressed as committed effective dose and cover a very wide range – seven orders of magnitude; however, it is believed that the method that produced the most extreme outlier incorporated an error equivalent to six orders of magnitude. If this outlier is excluded then the results still represented a discrepancy of over two orders of magnitude depending on which method was chosen.

Formatted: Left: 1.5 cm, Right: 1.75 cm
Deleted: techniques and
Deleted: and are used by different dosimetry laboratories and for different situations
Deleted: Over recent years there has been
Deleted: within the international dosimetry community to
Deleted: used and assuring a greater degree of correspondence in the monitoring and assessment of intakes by different laboratories
Deleted:
Deleted: 1
Deleted: 2
Deleted: EU-funded
Deleted: 3
Deleted: go a long way to
Deleted: which can be applied
Deleted: in
Deleted: al situatio
Deleted: ns
Deleted: ve
Deleted: the process of
Deleted: working
Deleted: some of
Deleted: challenges and potentially unforeseen consequences
Deleted: when
Deleted: these standards and guidelines
Deleted: encountered
Formatted: Space After: 6 pt
Deleted: ¶
Deleted:
Formatted Table
Deleted:

Table 2: predicted exposures from different models and assumptions

Predicted exposure (mSv/yr) For 100 kBq ^{239}Pu being processed in a fume hood			
Model #1 [7]	Model #2 [8]	Model #3 [9]	Model #4 [10]
8.4	8.4E-7	4.0	0.04

The other major drawback of using this algorithmic approach to estimating prospective dose is that it requires a presumption that the source term and the various protection factors are well known. This may be feasible for simple situations such as basic laboratory operations, but it is far from straightforward to extend this approach for use in more complex situations: e.g. large-scale industrial plant, decommissioning, waste management, remediation. If, for example, we consider a decommissioning operation that involves the dismantling and size-reduction of plant and material with dispersed radionuclide contamination, then it would be difficult to claim knowledge of the source term (or, at the least, that part of the contaminants which might pose a risk of exposure). Also, it would be highly implausible to claim prior knowledge of release fractions, dispersion and protection factors etc as these characteristics will be highly case-specific. The Nuvia dosimetry services have introduced a simple empirical procedure which is applied in these circumstances, as described in the following section.

1.1 Procedure for Deciding if Routine Monitoring is Required

Firstly, it is important to note that (in the UK) the employer has the legal duty for determining whether and how monitoring programmes should be implemented. The employer will seek advice on this matter from health physics professionals who will have the expertise and experience required to exercise appropriate judgement. The purpose of this procedure is not to over-rule or supplant such professional judgements, but to provide an objective basis to aid this judgement.

The dosimetry service reviews the operations in question to identify the nature of the internal dosimetry hazards and risks, and makes recommendations for appropriate monitoring programmes; the overview of this process has been described by Spencer et al [12]. If the operations require work within a designated controlled area and there is uncertainty whether routine monitoring is required then the dosimetry service will, as a default, recommend a routine monitoring programme for the purpose of assessing occupational internal dose.

This default recommendation may be mitigated if a review of all the available data and information implies that routine monitoring and dose assessment might not be necessary: i.e. if there were objective reasons to demonstrate confidence that potential doses would be below a given threshold. This conclusion would be supported by appropriate data and evidence – e.g. past dose results; air sample data; results from routine workplace survey. The review will determine the extent of the supporting data that is required, which will be determined partly by the potential hazards in the plant – e.g. a plutonium facility would need far stronger and extensive data to justify not monitoring in controlled areas than would, say, a purely beta-gamma facility.

If it is concluded that a routine monitoring programme is not to be implemented then the dosimetry service provides recommendations for how the hazard could continue to be effectively monitored and provide continuing justification that a routine programme, for dosimetry purposes, is not required. This will still require some form of ongoing monitoring arrangements, but these could be significantly less rigorous than programmes determined for the purpose of assessing dose: e.g. surface contamination surveys; workplace air sampling; limited individual monitoring. The dosimetry service also considers how effectively these in-direct monitoring methods are characterised with respect to potential exposures to workers; some examples for such characterisation have been reported previously[11][13].

This procedure is depicted in the flow chart is Figure 1.

Formatted Table

Formatted: Space After: 6 pt

Deleted: ¶

Deleted: proved

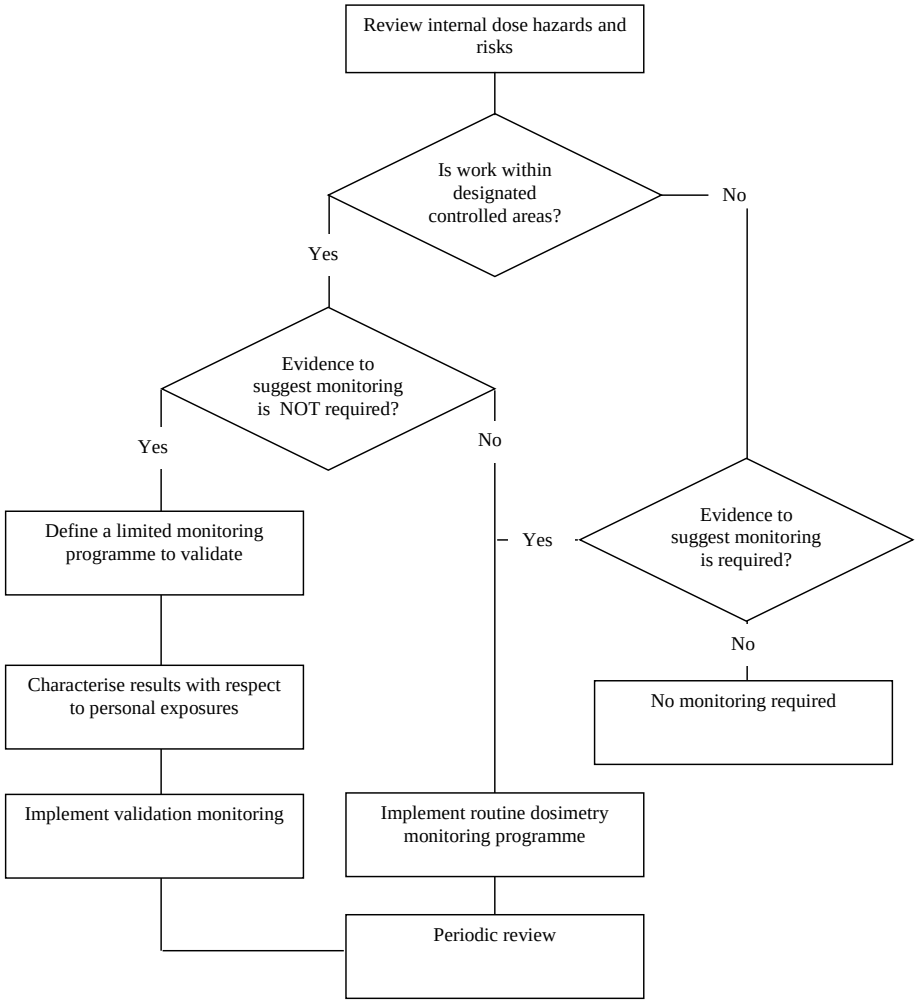

Fig. 1. Flow chart for deciding on the need for a routine dosimetry monitoring programme.

Deleted:

Deleted: Some examples of this are briefly described in the paper.¶

2. Testing The IDEAS Guidelines For Internal Dose Assessment

Monitoring of potential exposures to ever lower levels relies on bioassay measurements which are very close to the detection limits. This means that uncertainties in the measurement are proportionately more significant. The current IDEAS guidelines[2] for dose assessment employ an algorithm, with decision points to direct the assessor to various stages of an assessment. This is a useful tool; however, problems can arise when significant measurement uncertainties are introduced into this procedure. The uncertainties propagate through the assessment process, not only impacting on the modelling and final doses, but also on the decision points within the algorithm. Thus there is a risk of a step-change in the assessment process due to purely random factors: i.e. two identical exposures can lead to two significantly different assessments due to the measurement uncertainties.

Of particular interest is the application of these guidelines to the case where an intake is revealed by an above-action-level routine urine measurement. In this study realistic datasets are created numerically and subjected to the IDEAS methodology. The intakes and doses obtained in this way can be compared with the values used to create the dataset. The uncertainties in the process can be examined. In addition, it is possible to examine whether statistically outlying results can lead the guidelines along a false trail ending in a totally false assessment.

2.1. Setting up the Study

In this work a quarterly urine monitoring regime for 239Pu was considered. Three separate acute intake scenarios were considered: at the midpoint of the interval (day 45); one week before the next sample (day 83); the day before the next sample (day 89). It was assumed that the hypothetical worker had no previous exposure. In cases where the initial result lead to an estimated dose > 1 mSv, results from a follow-up urine and a follow-up faecal sample were available. These were assumed to be provided 30 days after the routine urine was voided. Various degrees of ignorance on the part of the assessor can be assumed. However, it was always assumed that he/she did not know the time of intake (other than the fact that it occurred sometime in the 90 day monitoring interval).

2.2. Creating the Datasets

For a given interval between intake and voiding, the code IMBA[14] was used to generate the theoretical excreted activity A, for a given set of parameters for lung solubility and particle size. In reality, the activity excreted on that day would be drawn from a lognormal distribution having A as its mean value (the median, M, of this distribution can easily be computed). This process can be represented numerically by using the MicroSoft Excel™ function loginv. Then loginv(rand(), ln(M),ln(g)) returns a random value a of the excreted activity drawn from a lognormal distribution with median M and geometric standard deviation g. In this work a value of 1.6 was used for g in the creation of urine datasets and a value of 3 in the creation of faecal datasets.

It is necessary to introduce further variability to mimic the uncertainty due to the analysis and measurement processes. Realistic parameters for counting statistics, background, calibration factor and recovery factors were used, based on experience. By combining the uncertainties derived from the expected mean excreted activity and those from the analysis and measurement of this activity it was possible to create artificial but realistic measurement data, such as would be normally presented to the dosimetry assessor. Datasets were constructed for separate 239Pu inhalations of 31 Bq (type M) and 120 Bq (type S), and a particle size represented by an AMAD of 5 microns in all cases. Both of these intakes correspond to a committed effective dose of 1 mSv.

Ten ‘case histories’ were generated for each assumption of type M and type S intakes, and for three different intake times at 45 days, 7 days and 1 day prior to the first sample: i.e. a total of sixty ‘case histories’ were generated; each one corresponding to a committed effective dose of 1 mSv. A ‘case history’ included an initial urine sample plus a follow-up urine and faecal sample provided at a realistic 30-day period after the initial sample.

2.3. Assessing the datasets

For this initial study it was assumed that the assessor did not know the date of the intake, but had, fortuitously, used default parameters for lung type (solubility), AMAD, and the scattering factor values for excreta which were the same as used to construct the data set. The assessor evaluated the data according to the IDEAS guidelines: This includes the estimate of dose as well as the prompt to acquire further data to refine the dose estimate. The outcomes of these tests are presented in Table 3 for type M intakes and Table 4 for type S intakes. These tables show, for each artificially created case, the resultant assessed intake and dose, together with an indication to which stage of the IDEAS Guidelines that particular assessment progressed to. Note: an explanation of the these

Formatted: Space After: 6 pt
Deleted: ¶
Deleted: Due to the need to m…nitoring of potential exposures
Deleted: requireswe need to perform assessments based on bioassay
Deleted: y…on bioassay measurements which are very close to
Deleted:
Deleted: outcomes… but they can…lso impact…on the decision
Deleted: . An example of this is givenillustrated in the paper
Deleted: ¶
Deleted: In this way t
Deleted: ¶
Deleted: ¶
Formatted
Deleted: ¶
Deleted: ¶
Formatted
Deleted: ¶
Deleted:
Formatted
Deleted: ¶
Deleted: ¶
Deleted: t

IDEAS 'stages' is not included in this paper, the main purpose is indicate where different cases progressed via different pathways of the branching algorithm contained in the Guidelines.

Table 3. Type M, 1 mSv cases

Table 3(a): **Intake at mid-point of 90 day interval**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage
1a	30	0.97	5.12.3
2a	19.6	0.64	3.5.1
3a	23	0.75	3.5.1
4a	16.5	0.54	3.5.1
5a	19.5	0.63	3.5.1
6a	27.5	0.9	5.12.3
7a	40.1	1.31	5.12.3
8a	27.4	0.89	3.5.1
9a	26.9	0.88	3.5.1
10a	29.8	0.97	3.5.1
mean	*26.03*	*0.848*	
sd	*6.80*	*0.22*	

Table 3(b): **Intake 1 week before routine sample**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage
1b	24.1	0.79	5.12.3
2b	30.2	0.98	3.5.1
3b	19.3	0.63	5.12.3
4b	56.8	1.85	5.12.3
5b	12.9	0.42	5.12.3
6b	52.3	1.7	5.12.3
7b	47.8	1.56	5.12.3
8b	41.2	1.34	5.12.3
9b	19.5	0.63	5.12.3
10b	89.7	2.92	5.12.3
mean	*39.38*	*1.282*	
sd	*23.32*	*0.76*	

Table 3(c): **Intake 1 day before routine sample**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage
1c	33.8	1.1	5.12.3
2c	33.1	1.08	5.12.3
3c	19.6	0.64	5.12.3
4c	28.9	0.49	5.15.1
5c	26.5	0.86	5.12.3
6c	33.8	1.1	5.12.3
7c	22.4	0.73	5.12.3
8c	27.6	0.9	5.12.3
9c	58.7	1.91	5.12.3
10c	41.1	1.34	5.12.3
mean	*32.55*	*1.015*	
sd	*11.08*	*0.40*	

Deleted: ¶
Formatted
Deleted: ¶
Formatted Table
Deleted: Stage assessment
Deleted: case
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Deleted:
Deleted:
Formatted
Deleted: ¶
Formatted
Deleted: …ntake 1 week before routine sample ¶
Deleted:
Deleted: case
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Deleted:
Formatted
Deleted:
Deleted: ¶
Formatted
Deleted: ¶
Deleted:
Deleted: case
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted
Formatted

Table 4. type S, 1 mSv cases

Table 4(a): **Intake at mid-point of 90 day interval**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage
1a	0	0	1.2.1
2a	219	1.83	5.12.3
3a	0	0	1.2.1
4a	0	0	1.2.1
5a	70	0.59	5.12.3
6a	107	0.9	3.5.1
7a	12.2	0.1	3.5.1
8a	49	0.41	5.16.1
9a	296	2.47	5.12.3
10a	0	0	1.2.1
mean	*75.32*	*0.63*	
sd	*104.21*	*0.87*	

Table 4(b): **Intake 1 week before routine sample**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage
1b	356	2.98	5.12.3
2b	150	1.25	5.12.3
3b	0	0	1.2.1
4b	0	0	1.2.1
5b	18.4	0.15	3.5.1
6b	69	0.57	3.5.1
7b	57	0.48	5.16.1
8b	283	2.37	5.12.3
9b	0	0	1.2.1
10b	301	2.52	5.12.3
mean	*123.44*	*1.032*	
sd	*139.80*	*1.17*	

Table 4(c): **Intake 1 day before routine sample**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage
1c	339	2.84	5.12.3
2c	43.57	0.43	5.15.1
3c	66.84	0.64	5.15.1
4c	10.7	0.35	5.12.3
5c	134	1.12	5.12.3
6c	647	5.41	5.15.1
7c	6.7	0.22	5.12.3
8c	40.07	0.41	5.15.1
9c	10.4	0.34	5.12.3
10c	584	4.89	5.12.3
mean	*188.23*	*1.67*	
sd	*246.42*	*2.00*	

This study was repeated exactly as above but with the exception that this time is was assumed that the default lung type used at the start of the assessment was different to that used to create the data sets: i.e. for data sets created for a intake of type M material then the assessment started with an assumption of type S, and vice versa. The purpose of this was to test whether the guidelines would lead the assessor to assume the 'correct' value for lung type. The results are presented in Tables 5 & 6.

Deleted: ¶

mid-point			
Summary case	Assessed Intake Bq	Dose mSv	Stage assessment terminated
1a	0	0	1.2.1
2a	219	1.83	5.12.3
3a	0	0	1.2.1
4a	0	0	1.2.1
5a	70	0.59	5.12.3
6a	107	0.9	3.5.1
7a	12.2	0.1	3.5.1
8a	49	0.41	5.16 ?
9a	296	2.47	5.12.3
10a	0	0	1.2.1
mean	75.32	0.63	
sd	104.21	0.87	
week before			
Summary case	Assessed Intake Bq	Dose mSv	Stage assessment terminated
1b	356	2.98	5.12.3
2b	150	1.25	5.12.3
3b	0	0	1.2.1
4b	0	0	1.2.1
5b	18.4	0.15	3.5.1
6b	69	0.57	3.5.1
7b	57	0.48	5.16 ?
8b	283	2.37	5.12.3
9b	0	0	1.2.1
10b	301	2.52	5.12.3
mean	123.44	1.032	
sd	139.80	1.17	
l day before			
Summary case	Assessed Intake Bq	Dose mSv	Stage assessment terminated
1c	339	2.84	5.12.3
2c	43.57	0.43	5.15.1
3c	66.84	0.64	5.15.1
4c	10.7	0.35	5.12.3
5c	134	1.12	5.12.3
6c	647	5.41	5.15.1 further samp
7c	6.7	0.22	5.12.3
8c	40.07	0.41	5.15.1
9c	10.4	0.34	5.12.3
10c	584	4.89	5.12.3
mean	188.228	1.665	
sd	246.42	2.00	

Deleted:

Formatted Table

Deleted: ¶

Formatted

Formatted

Deleted: ¶

Deleted: case

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Deleted: ¶

Formatted

Deleted:

Deleted: case

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Table 5: Type M, 1 mSv intakes, initially assessed as type S.

Table 5(a): **Intake at mid-point of 90 day interval**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage	solubility
1a	30	0.97	5.12.3	M
2a	45.3	1.47	5.12.3	M
3a	6.5	0.21	5.12.3	M
4a	17.1	0.56	5.12.3	M
5a	18.8	0.61	5.12.3	M
6a	27.5	0.9	5.12.3	M
7a	40.1	1.31	5.12.3	M
8a	20.6	0.67	5.12.3	M
9a	25.4	0.83	5.12.3	M
10a	35.7	1.16	5.12.3	M
mean	*26.7*	*0.869*		
sd	*11.64*	*0.38*		

Table 5(b): **Intake 1 week before routine sample**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage	solubility
1b	24.1	0.79	5.12.3	M
2b	36.2	1.18	5.12.3	M
3b	21.9	0.71	5.12.3	M
4b	56.8	1.85	5.12.3	M
5b	12.9	0.42	5.12.3	M
6b	52.7	1.7	5.12.3	M
7b	47.8	1.56	5.12.3	M
8b	41.2	1.34	5.12.3	M
9b	19.5	0.63	5.12.3	M
10b	89.7	2.92	5.12.3	M
mean	*40.28*	*1.31*		
sd	*21.74*	*0.71*		

Table 5(c): **Intake 1 day before routine sample**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage	solubility
1c	33.8	1.1	5.12.3	M
2c	33.1	1.08	5.12.3	M
3c	19.6	0.64	5.12.3	M
4c	28.9	0.49	5.15.1	M
5c	26.5	0.86	5.12.3	M
6c	33.8	1.1	5.12.3	M
7c	22.4	0.73	5.12.3	M
8c	27.6	0.9	5.12.3	M
9c	58.7	1.91	5.12.3	M
10c	41.1	1.34	5.12.3	M
mean	*32.55*	*1.015*		
sd	*11.08*	*0.40*		

Deleted: ¶

Deleted: ¶

Deleted:

mid-point Summary case	Assessed Intake Bq	Dose mSv	Stage assessment terminated	Best f solubil
1a	30	0.97	5.12.3	M
2a	45.3	1.47	5.12.3	M
3a	6.5	0.21	5.12.3	M
4a	17.1	0.56	5.12.3	M
5a	18.8	0.61	5.12.3	M
6a	27.5	0.9	5.12.3	M
7a	40.1	1.31	5.12.3	M
8a	20.6	0.67	5.12.3	M
9a	25.4	0.83	5.12.3	M
10a	35.7	1.16	5.12.3	M
mean	26.7	0.869		
sd	11.64	0.38		
week before Summary case	Assessed Intake Bq	Dose mSv	Stage assessment terminated	Best f solubil
1b	24.1	0.79	5.12.3	M
2b	36.2	1.18	5.12.3	M
3b	21.9	0.71	5.12.3	M
4b	56.8	1.85	5.12.3	M
5b	12.9	0.42	5.12.3	M
6b	52.7	1.7	5.12.3	M
7b	47.8	1.56	5.12.3	M
8b	41.2	1.34	5.12.3	M
9b	19.5	0.63	5.12.3	M
10b	89.7	2.92	5.12.3	M
mean	40.28	1.31		
sd	21.74	0.71		
1 day before Summary case	Assessed Intake Bq	Dose mSv	Stage assessment terminated	Best f solubil
1c	33.8	1.1	5.12.3	M
2c	33.1	1.08	5.12.3	M
3c	19.6	0.64	5.12.3	M
4c	28.9	0.49	5.15.1	M
5c	26.5	0.86	5.12.3	M
6c	33.8	1.1	5.12.3	M
7c	22.4	0.73	5.12.3	M
8c	27.6	0.9	5.12.3	M
9c	58.7	1.91	5.12.3	M
10c	41.1	1.34	5.12.3	M
mean	32.55	1.015		
sd	11.08	0.40		

Deleted:

Formatted Table

Deleted: ¶

Formatted

Deleted: ¶

Deleted:

Deleted: case

Deleted: Intake Bq

Deleted: mSv

Deleted: terminated

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Deleted: ¶

Formatted

Deleted: ¶

Deleted:

Deleted: case

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Table 6: Type S, 1 mSv intakes, initially assessed as type M

Table 6(a): **Intake at mid-point of 90 day interval**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage	solubility
1a	0	0	1.2.1	M
2a	8.4	0.27	3.5.1	M
3a	0	0	1.2.1	M
4a	0	0	1.2.1	M
5a	6.9	0.22	3.5.1	M
6a	2.1	0.07	3.5.1	M
7a	0	0	1.2.1	M
8a	3.4	0.11	3.5.1	M
9a	4.7	0.15	3.5.1	M
10a	0	0	1.2.1	M
mean	*2.55*	*0.082*		
sd	*3.18*	*0.10*		

Table 6(b): **Intake 1 week before routine sample**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage	solubility
1b	9.7	0.32	3.5.1	M
2b	3.9	0.13	3.5.1	M
3b	0	0	1.2.1	M
4b	0	0	1.2.1	M
5b	0	0	1.2.1	M
6b	1.3	0.04	3.5.1	M
7b	5.5	0.18	3.5.1	M
8b	9.6	0.31	3.5.1	M
9b	0	0	1.2.1	M
10b	13.4	0.44	3.5.1	M
mean	*4.34*	*0.142*		
sd	*5.00*	*0.16*		

Table 6(c): **Intake 1 day before routine sample**

Case	Assessed Intake (Bq)	Dose (mSv)	End stage	solubility
1b	4.7	0.15	3.5.1	M
2b	132	1.1	5.12.3	S
3b	137	1.15	5.12.3	S
4b	30	0.98	3.5.1	M
5b	11.8	0.38	3.5.1	M
6b	28.3	0.92	3.5.1	M
7b	6.6	0.22	5.12.3	M
8b	148	1.24	5.12.3	S
9b	29	0.95	3.5.1	M
10b	26	0.85	3.5.1	M
mean	*55.34*	*0.794*		
sd	*58.59*	*0.40*		

2.4. Discussion

Numerically-generated datasets have been used to test the IDEAS guidelines for internal dose assessment. These datasets represent intakes of inhalation type M and type S material corresponding to committed effective doses of 1 mSv.

When the assessor makes a correct initial assumption of the solubility type, the assessed doses for type M intakes are quite close to the nominal values, regardless of the intake date within the monitoring interval. The dispersion

Deleted: ¶

Deleted: ¶

Formatted

Deleted: ¶

Deleted:

mid-point Summary case	Assessed Intake Bq	Dose mSv	Stage assessment terminated	Solu used i asses
1a	0	0	1.2.1	
2a	8.4	0.27	3.5.1	
3a	0	0	1.2.1	
4a	0	0	1.2.1	
5a	6.9	0.22	3.5.1	
6a	2.1	0.07	3.5.1	
7a	0	0	1.2.1	
8a	3.4	0.11	3.5.1	
9a	4.7	0.15	3.5.1	
10a	0	0	1.2.1	
mean	2.55	0.082		
sd	3.18	0.10		
week before Summary case	**Assessed Intake Bq**	**Dose mSv**	**Stage assessment terminated**	**Solu used i asses**
1b	9.7	0.32	3.5.1	
2b	3.9	0.13	3.5.1	
3b	0	0	1.2.1	
4b	0	0	1.2.1	
5b	0	0	1.2.1	
6b	1.3	0.04	3.5.1	
7b	5.5	0.18	3.5.1	
8b	9.6	0.31	3.5.1	
9b	0	0	1.2.1	
10b	13.4	0.44	3.5.1	
mean	4.34	0.142		
sd	5.00	0.16		
day before Summary case	**Assessed Intake Bq**	**Dose mSv**	**Stage assessment terminated**	**Solu used i asses**
1b	4.7	0.15	3.5.1	
2b	132	1.1	5.12.3	
3b	137	1.15	5.12.3	
4b	30	0.98	3.5.1	
5b	11.8	0.38	3.5.1	
6b	28.3	0.92	3.5.1	
7b	6.6	0.22	5.12.3	
8b	148	1.24	5.12.3	
9b	29	0.95	3.5.1	
10b	26	0.85	3.5.1	
mean	55.34	0.794		
sd	58.59	0.40		

Deleted:

Formatted Table

Deleted: ¶

Formatted

Deleted: ¶

Deleted:

Deleted: case

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Deleted: ¶

Formatted

Deleted: ¶

Deleted:

Deleted: case

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

Formatted

in the assessed doses is greater for the type S datasets, though the mean and median values are still close to the nominal values. However, intakes modelled as occurring early in the monitoring regime are sometimes 'missed' in that the low urine activity causes the assessment to branch to 'record dose as zero' at an early stage. This fact demonstrates the difficulties in monitoring for small intakes of insoluble ^{239}Pu using urine sampling alone.

When the assessor initially treats the type M intakes as type S, the guidelines always steer the assessment to the correct (type M) solubility and the resulting assessed doses again lie close to the nominal value. More problems arise when the assessor initially treats type S intakes as type M. In a large proportion of cases the guidelines direct the assessor to record the dose as zero. As a result the median and mean of the assessed doses lie well below the nominal value of 1 mSv.

It is of interest to examine the effect of imposing an action level on the routine urine results. If the action level was set at 0.2 mBq/day, then 3 out of 30 of the type M intakes (all modelled to occur at the beginning of the sampling period) would not be assessed. All but 8 out of 30 of the type S intakes would not be assessed. These 8 cases are amongst those modelled to occur on the day before sampling.

This study shows that the application of the IDEAS Guidelines provide reasonably reliable dose estimates at 1 mSv CED for type M ^{239}Pu. However, these results emphasise the difficulties in routine urine monitoring for type S material, but it is noteworthy that a correct default assumption of solubility type greatly improves the assessment of the relatively small type S intakes.

3. Conclusions

The production of appropriate Standards and Guidance is undoubtedly of significant benefit and value to the field of occupationally dosimetry; however, both of the reviews described in this paper emphasise that their application to practical situations requires careful consideration and awareness of the potential limitations and highlights the need for expert internal dosimetry practitioners whose understanding goes beyond the application of the available guidelines.

4. References

[1] International Organization for Standardization, 2006, *Radiation Protection - Monitoring of Workers Occupationally Exposed to a Risk of Internal Contamination with Radioactive Material*, ISO 20553 (ISO)

[2] Doerfel, H., Andrasi, A., Bailey, M., Berkovski, V., Blanchardon, E., Castellani, CM., Hurtgen, C., Le Guen, B., Malatova, I., Marsh, J., et al., 2006, *General Guidelines for the Estimation of Committed Effective Dose from Incorporation Monitoring Data*. Report FZKA 7243, (Forschungszentrum Karlsruhe GmbH)

[3] Health and Safety Executive (UK), 1999, *Ionising Radiations Regulations 1999 Approved code of practice and guidance*, (HSE)

[4] International Commission on Radiological Protection, 1990, *1990 Recommendation of the International Commission on Radiologica Protection.* ICRP Publication 60 (Pergammon)

[5] International Commission on Radiological Protection, 1997, *Individualmonitoring for internal exposure of workers.* ICRP Publication 78 (Pergammon)

[6] International Atomic Energy Agency, 1996, *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources*. Safety Series no. 115 (IAEA, Vienna)

[7] International Atomic Energy Agency, 1999, *Assessment of occupational exposure due to intakes of radionuclides*. Safety Standards Series no. RS-G-1.2 (IAEA, Vienna)

[8] U.S. Nuclear Regulatory Commission (NRC), 1993, *Air Sampling in the Workplace*. NUREG-1400 (NRC)

[9] UKAEA. *Safety Assessment Handbook*, 2007 (UKAEA)

[10] Shaw, P. V., Hudson, A. P., Grindrod, E. L., 1998,. *Memorandum – Guidance on Monitoring and Dose Assessment for Internal Exposure of Workers*. NRPB-M900 (NRPB)

Deleted: ¶

Deleted: ¶

Deleted: ¶

Deleted: ¶

Deleted: ¶

Deleted: .¶
¶

Deleted: ¶

Deleted:

Deleted: .

Deleted:

Deleted: .

Deleted: s

Deleted: .

Deleted:

Deleted: .

Deleted:

Deleted: .

Deleted:

Deleted: .

Deleted:

[11] Roberts, G., 2010, *The Determination of when Routine Internal Dosimetry Monitoring Is Required*, in proc. ISOE International Symposium, November 2010, Cambridge, UK

[12] Spencer, D., Roberts, G., Smith, D., 2001, *Dosimetry control systems at Dounreay*, in proc. Radiation Dose Management in the Nuclear Industry, 14-16 May 2001, Windermere, UK.

[13] Roberts, G., 2006, *Internal Dosimetry Hazard and Risk Assessments: Methods and Applications*, in proc. Second European IRPA Congress, May 2006, Paris

[14] Birchall, A., Puncher, M., James, A. C., Marsh, J. W., Jarvis, N. S., Peace, M. S., Davis, K. and King, D. J., 2003, *IMBA Expert ^{TM}: internal dosimetry made simple*. Radiat. Prot. Dosim. **105**(1-4), 421-425.

Deleted:

Deleted:

Deleted:

Deleted: