The Determination of when Routine Internal Dosimetry Monitoring Is Required

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ABSTRACT

Routine internal dose exposures are typically (in the UK nuclear industry) less than external dose exposures: however, the costs of internal dosimetry monitoring programmes can be significantly greater than those for external dosimetry. For this reason decisions on when to apply routine monitoring programmes, and the nature of these programmes, can be more critical than for external dosimetry programmes. The UK Ionising Radiations Regulations [1] require that all *significant* doses are assessed and recorded, and the Approved Code of Practice [2] advise that decisions on when monitoring is required is determined by the *expected magnitude and variability* of personal dose. This leaves the practical problem of how to quantify the expected dose while avoiding the "*Catch-22*" situation of implementing extensive monitoring programmes simply to provide evidence that they were not required.

This paper describes various internal dosimetry risk assessment methods which are employed by Nuvia Limited Approved Dosimetry Services to attempt to provide an objective assessment of when routine internal dosimetry monitoring should be considered. It also discusses the possible shortcomings of these process and potential future development. The paper argues that, for most instances in the nuclear industry, the principle objective of routine internal monitoring programmes is not to monitor *exposure* to internal dose, but to monitor for the *risk* of exposure; thereby indicating when more thorough investigations and dose estimation is required, and also providing important feedback to the efficacy of radiological protection measures.

INTRODUCTION

The Nuvia Limited Approved Dosimetry Services (ADS), based at Harwell, have been providing dosimetry services since 1948, supporting the UK's civil nuclear research and development programmes and, latterly, decommissioning programmes. An important element of these services is the internal dosimetry of the more radiotoxic elements associated with the nuclear fuel cycle, such as plutonium and americium, for which the ADS has extensive experience of providing internal dosimetry to a wide range of different sites, organisations and operations across the UK and internationally.

The introduction of internal monitoring programmes can be a significant decision in terms of cost, disruption and, occasionally, their acceptance by the workforce. The ADS has been attempting to identify some objective methods and criteria that would aid the decision making process. This endeavour is ongoing, and this paper provides a summary of the methods currently being explored, including some practical examples which, due to the provisional nature of these studies, are reported as simplified hypothetical studies for illustration purposes only. It is intended that more detailed data will be published later.

EXISTING GUIDANCE

ICRP Publication 60 [3] states that …

"(268) Individual monitoring for intakes of radioactive material … should be used routinely only for workers who are employed in areas that are designated as controlled areas specifically in relation to the control of contamination and in which there are grounds for expecting significant intakes. …"

ICRP Publication 78 [4] expands the above statement to …

"(11) …Routine monitoring would only be required in conditions of essentially continuous risk of contamination of the workplace as a result of normal operations…"

This principle is restated in IAEA Basic Safety Standard [5]…

"I.33 …For any worker who is normally employed in a controlled area, or who occasionally works in a controlled area and may receive significant occupational exposure, individual monitoring shall be undertaken where appropriate, adequate and feasible…"

and ISO 20553 [6] …

"The purpose of monitoring, in general, is to verify and document that the worker is protected adequately against risks from radionuclide intakes and the protection complies with legal requirements. Therefore, it forms part of the overall radiation protection programme, which starts with an assessment to identify work situations in which there is a risk of radionuclide intake by workers, and to quantify the likely intake of radioactive material and the resulting committed effective dose received. Decisions about the need for monitoring and the design of the monitoring programme should be made in the light of such a risk assessment."

UK REGULATION

UK regulation and associated guidance [1][2] advise that routine monitoring for a specific component of dose (e.g. as arising from intakes of radionuclides) may not be required, provided that the expected magnitude of the dose does not exceed 1 mSv per year, taking into account the expected variability of the dose.

PRACTICAL APPLICATON

These statements express some basic principles but do not directly provide a practical methodology. The following paragraphs present arguments which are proposed as the basis for a practical and objective application of the principles expressed above.

Monitoring Risk, Not Dose

The ADS has no knowledge of any situation where the workforce is routinely exposed to significant doses (> 1 mSv/year) from highly radiotoxic elements such as plutonium or americium. The rate of occurrence of acute exposure events that would give rise to doses > 1 mSv is very low, although not nil. For these reasons the practical objective of routine monitoring (for highly radiotoxic elements) is to monitor for the occurrence of an exposure and to provide reassurance that significant exposures have not occurred, rather than for the routine assessment of dose.

The null hypothesis: determine that risks do not need monitoring, rather than whether monitoring is needed

The guidance expressed above imply that some form of prior knowledge is required of the expected intake or of the risks of significant intakes. This is reasonably achievable for

operations and hazards which are continuing and essentially unchanging, and for which past data is available. However, this is not normally practicable for new or substantially changed operations. The current ADS approach is to start from the default presumption that routine internal monitoring should be advised for all classified workers who routinely work in contamination-controlled areas, unless there is evidence to demonstrate that significant exposures or risks of exposure are not expected. This approach more definitely places the onus on the requirement to demonstrate that monitoring is not required, rather than attempting to decide whether it is required or not. This is perhaps a simplistic and overly cautious interpretation of the existing guidance; however, it does provide an objective method.

A 'good' risk assessment is implicitly capable of being falsified

Risk assessments should be able to make predictions that can be practicably and empirically tested, the results of which should be capable of rejecting the original risk assessment, in which circumstance the risk assessment should be reviewed and revised or replaced. This is especially important for highly radiotoxic elements where even reasonably small uncertainty in the quantities and characteristics of these elements (and, thereby, the risk) can translate to relatively large dose consequences.

ILLUSTRATIONS

Several studies and reviews are currently in progress which seek to apply these proposals for real operations at a number of locations. However, these studies have not been concluded nor finally agreed with the clients; therefore, a number of examples of simplified hypothetical cases are provided to illustrate how the arguments presented above may be used objectively in realistic situations. It is intended that the results of the real studies will be published at a later time.

Example 1: high containment facility with remote handling operations

In this case the risk assessment may simply refer to the engineered controls as 'evidence' that significant exposures are not expected. Because the containment is cited as the 'evidence' for the risk assessment then any breach of containment would reject the risk assessment and prompt a review. This is easily monitored by routine workplace surveys, so no individual monitoring is required; a positive survey result would prompt a review of the risk assessment and/or operations and/or monitoring programmes.

Example 2: general access and operational areas of process plant

This may apply to larger plant where the potential sources of exposure are restricted to limited areas and operations, but where there is the potential for transport of contamination to other areas. The risk assessment for the general areas would recognise this potential but claim that the magnitude and variability of expected exposures are not significant. Three different options for testing this risk assessment are considered…

2a: Workplace air sampling (Static Air Samplers)

Static Air Samplers (SAS) are positioned to provide representative samples of the breathing air in the workplace. The results of the SAS sampling requires to be characterised with respect to potential exposure by the measurement of correction factors[7]. The ongoing review of the results of the SAS programme can then be used as a test of the original risk assessment. The main drawbacks for this method are that a large number of SAS units may be required to provide adequate statistics; positioning of SAS units need to take into account building ventilation and air flow patterns, which would need to be reasonably stable; SAS may significantly underestimate or fail to detect highly localised exposures.

2b: Personal air sampling (PAS)

The efficacy of individual PAS measurements is a matter for on-going debate; however, several studies have concluded that average intakes determined from large numbers of PAS (e.g. for a group of workers) can provide reasonable correlations to intakes based on bioassay measurements [8][9] . PAS campaigns of 1 to 2 months are initiated in the general areas of the plant. The assumption is made that there is a uniform risk of exposure throughout these areas; therefore, the PAS samples can be considered to be samples taken from a coherent population. Analysis of the distribution of results can then be used to derive information about the variability in the risk. Some provisional data is presented in Figure 1: this shows a distribution which is reasonably approximated by a normal distribution (the solid line), but with a mean of less than zero. This probably indicates that the distribution is dominated by measurement uncertainties and the presence of a slight negative bias in the measurement method.

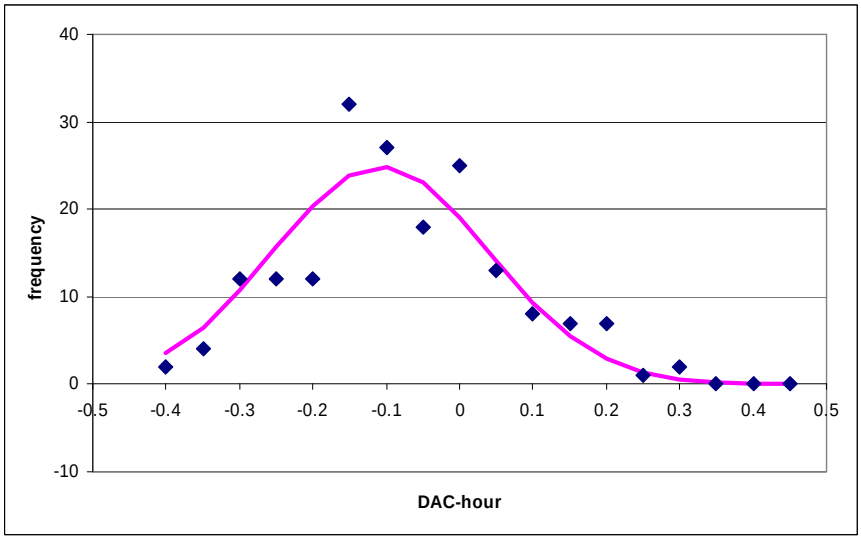

Figure 1: distribution of PAS sample results (points) and normal distribution (line)

This data may be extrapolated to expected annual exposure at the 95% confidence level by the formula [1]:

$$\mathbf{n.x + 1.645.\ \sqrt{(\ n.s^2)}} \qquad [1]$$

n = number of days worked in area
x = mean daily exposure derived from PAS campaign
s = standard deviation derived from above distribution

In this example the 95% confidence level would provide a result less than zero, which strongly indicates that expected exposures and their variability are not significant – but also indicates that a review of the measurement methods is required.

2c: Limited individual monitoring

Individual monitoring is introduced on a limited basis: this may be to monitor for only one part of the potential hazard at a low frequency as a 'tracer' for the whole hazard. In this example the relative inventory of radioisotopes is listed in Table 1. It is decided to instigate an annual whole body monitoring (WBM) programme. This will be able to detect the ^{137}Cs and ^{60}Co components very easily, with an investigation level at 200 Bq (each isotope).

Table 1: relative inventory and dosimetric hazard normalized by dose coefficients

Isotope	Inventory (% Bq)	LungType	DoseCoef(Sv/Bq)	Normalized hazard
Am241	0.04	M	2.70E-05	4.42E-01
Co60	30	S	1.70E-08	2.09E-01
Cs137	69.92	F	6.70E-09	1.92E-01
Pu238	0.02	S	1.10E-05	9.00E-02
Pu239	0.02	S	8.30E-06	6.79E-02

By using the ^{137}Cs and ^{60}Co measurements as tracers it is seen from Table 1 that we are monitoring 40% of the normalized hazard. For a WBM measurement of 200 Bq for both isotopes, and then correcting for the normalized hazard, the dose sensitivity is approximately 0.3 mSv/year. This is an inference which is very dependent on the recorded isotopic ratios, for which we have no recorded uncertainty; however, since we are directly monitoring a significant proportion of the hazard, and that the inferred dose sensitivity is more than a factor of 3 less than the significant level of 1 mSv/year, then this programme may be assumed to provide reasonable evidence that significant exposures are not expected. This assumption would be questioned if WBM measurements greater than the investigation level of 200 Bq were recorded. Periodic measurements of the isotopic mix would also be required; if the relative isotopic abundances differed significantly then this would also prompt a review of the risk assessment.

Example 3: plutonium operations in fume hood

In this case there is an obvious potential for localised exposures; however, the process control for this facility limits the total amount of plutonium-239 that can be processed to 100 kBq per year. It is also believed that the plutonium is most likely to be of insoluble dry powder form. There are a number of risk-assessment type algorithms which have been published which are able to incorporate this source data and calculate predictive values of exposure; four are used for this illustration: IAEA [10]; NRC [11]; UKAEA [12]; NRPB [13]. These algorithms use various factors and coefficients to relate a source to a predicted exposure; however, it is not intended to examine these methods in detail in this paper. It is noted that these methods may have been intended for different purposes, and, therefore, the data presented here is purely observational and not meant as a critical review. Table 2 presents the outcome of these different algorithms as applied to this scenario.

Table 2: predicted exposures from different models and assumptions

Predicted exposure (mSv/yr)			
IAEA[1]	NRC[2]	UKAEA[3]	NRPB[4]
8.4	8.4E-7	4.0	0.04

Notes:
1. Includes factors for containment, physical form and process
2. Includes factors for containment and release fractions; and also a factor of 1E-6 based on observations relating processed activity to measured intakes.
3. Based on the assumption of failed containment and release of total inventory (100 kBq) dispersed as a hemispherical cloud with operator at 0.5 m.
4. Based on the assumption of one substantial spill per year, and includes re-suspension and containment factors.

Very different outcomes can be obtained depending on which method is used, and it is not obvious which of these methods should be preferred over the others. For this reason the ADS would avoid using such algorithms as ‘evidence’ that routine individual monitoring need not be applied.

SUMMMARY

Existing guidance express the principles for determining when routine individual monitoring programmes should be introduced; however, these expressions do not directly provide an objective method for practical application. This paper presents arguments which are proposed as the basis for a practical and objective application of these principles; and offers some illustrations as examples of different ways that this may be achieved in practice. A number of organisations have published mathematical algorithms which purport to enumerate the potential dose or risk from a defined source term; however, these algorithms can produce significantly different outcomes. It is recommended that a more detailed critical review be undertaken of the use of such algorithms.

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