Personal Dosimetry Management

A Nuclear Industry Good Practice Guide

This Issue of the Nuclear Industry Good Practice Guide on Personal Dosimetry Management was published by the Industry Radiological Protection Co-ordination Group (IRPCG) on behalf of the Nuclear Industry Safety Directors Forum (SDF) in 2011

Page intentionally left blank

The Industry Radiological Protection Co-ordination Group (IRPCG) recognises that, as use and experience of this Good Practice Guide grows: there may well be comments, questions and suggestions on the content. IRPCG is committed to maintaining and updating the GPG so that it continues to represent good practice, and welcomes any such comments on the Guide. Comments should, in the first instance, be sent to the IRPCG chairman who can be contacted via the IRPCG website

http://irpcg.org/

Page intentionally left blank

Foreword

Personal Dosimetry, in one form or another is required to record and manage personal dose associated with work with ionising radiation. This Good Practice Guide (GPG) details the principles and practices that are considered to be nuclear industry good practice.

It is not and should not be read as a code of practice, it solely provides a reference that can be utilised by nuclear industry practitioners when instigating or updating their dosimetry management processes and practices. Also the issue of this GPG is not intended to initiate wholesale review of existing arrangements where there is no other driver to do so.

The (Nuclear) Industry Radiological Protection Co-ordination Group (IRPCG), which is a working group set up by the Nuclear Industry Safety Directors Forum (SDF), reviewed the approaches to personal dosimetry utilised across the nuclear industry. The review found that there were a variety of approaches applied to dosimetry practice and implementation. It was also the case that relevant standards and guidance had been extant for some time, and hence would benefit from review.

As a direct result, the IRPCG set up a sub-group consisting of relevant experts from member organisations with the following objective:

'*Develop and make available to the Nuclear Industry a Dosimetry Management Good Practice Guide*'

This GPG is believed to be consistent with all relevant legislation and guidance, and has so far been endorsed by the following organisations:

- AWE Plc
- Babcock International Group – Marine and Technology Division
- Dounreay Site Restoration Limited
- EDF Energy Nuclear Generation
- GE Healthcare Ltd
- Magnox
- Ministry of Defence
- Rolls-Royce
- Research Sites Restoration Limited
- Sellafield Limited
- Springfields Limited

This GPG has been the subject of extensive review and consultation amongst relevant stakeholders. However, as with any such Guide, publication may lead to a call for further advice, or for other aspects to be considered. The IRPCG will keep this GPG under review, and strongly encourages users to comment, ask questions or make suggestions on the content of this Guide. IRPCG undertakes to respond to any such comment and will revise and re-issue the GPG as necessary. Contact information is given on the inside front cover of this Guide.

Finally, the IRPCG take this opportunity to thank all of the members of the Dosimetry Good Practice Guide Working Group for the time and effort that they have put into producing this guide.

Revisions Sheet

Issue Number	Date	Comments
Draft	Sep 2011	Final Draft for IRPCG and Working Group final comments
1st Issue	Nov 2011	For initial distribution and comment

This publication is scheduled for review 2014

.

Contents

1. INTRODUCTION

In 2008 the Nuclear Industry Safety Directors Forum (SDF) requested that the Industry Radiological Protection Co-ordination Group (IRPCG) review the Dosimetry arrangements within the UK Nuclear Industry. The IRPCG established that although there was generally acceptable practice it was not consistent and it was not clear what constituted industry good practice. In particular:

- The dosimetry requirements for radiation workers vary from site to site
- There was no agreement as to what constitutes good dosimetry practice
- It was not possible for site employers to establish whether they were achieving good industry practice
- Relevant standards and guidance had been extant for some time, and hence would benefit from review

As a direct result, the IRPCG set up a sub-group consisting of relevant experts from member organisations with the objective to '*Develop and make available to the Nuclear Industry a Dosimetry Management Good Practice Guide (GPG)*'. This publication is the result of the work of that group, details of membership of the group can be found at Annex 1.

Personal monitoring of the individual exposure of workers constitutes an integral part of any radiation protection programme: however what is considered good practice varies depending upon the specific site requirements and circumstances. There are general principles and good practice that can be carried across the many and varied sites. Also it is worth noting that although the objectives and fundamental principles of dose record keeping have not changed particularly over the years, huge developments in information technology, such as easy access to storage media and wider Internet use, have had an impact on dose recording, dose data transfer and dose record keeping. Other specific changes/updates include 'state of the art' knowledge on the application of dosimetry, protection and operational quantities in agreement with ICRU and ICRP recommendations, development and introduction of electronic dosimetry.

This Guide aims to describe the provision of dosimetry services and management from the perspective of the nuclear industry radiation employers responsibilities with regards to establishing, meeting and providing the employers dosimetry arrangements. These are normally met by the employer establishing one or more offices, with any number of staff located in a number of locations, but are referred to within this Guide in the singular as the site employer or site employer's arrangements. This Guide looks at the actions and requirements related to these responsibilities and how the site employer can meet these responsibilities when acting as a nuclear industry radiation employer. It should be noted that for the purposes of this Guide it is assumed that the nuclear industry radiation employer is a Nuclear Site Licensee or an operator of a similar large nuclear facility or a major supporter of such facilities.

The dosimetry related drivers and interfaces impacting on a typical licensed site employer are many and varied. Figure 1 shows the complex nature of these drivers. This GPG addresses the dosimetry related issues from the perspective of the nuclear industry employer, concentrating on the service provided by the site employer. Chapter 2 addresses the drivers and expectations such as legal requirements, recognised standards, and other various requirements, the chapter calls heavily on relevant national and international technical reports and recommendations [1, 2, and 14]. Chapter 3 covers the general

principles of dosimetry provision from the site employer's perspective. Chapter 4 addresses requirements related to external whole body and extremity dosimetry, looking at the types and uses of various dosimetry solutions available. Chapter 5 looks at provision of and issues related to internal dosimetry. Chapter 6 relates to how personal dose record management and the various interfaces and challenges can be addressed. Chapter 7 addresses the wider issue of collective dose management. Finally chapter 8 provides good practice scenarios and illustrations of good practice.

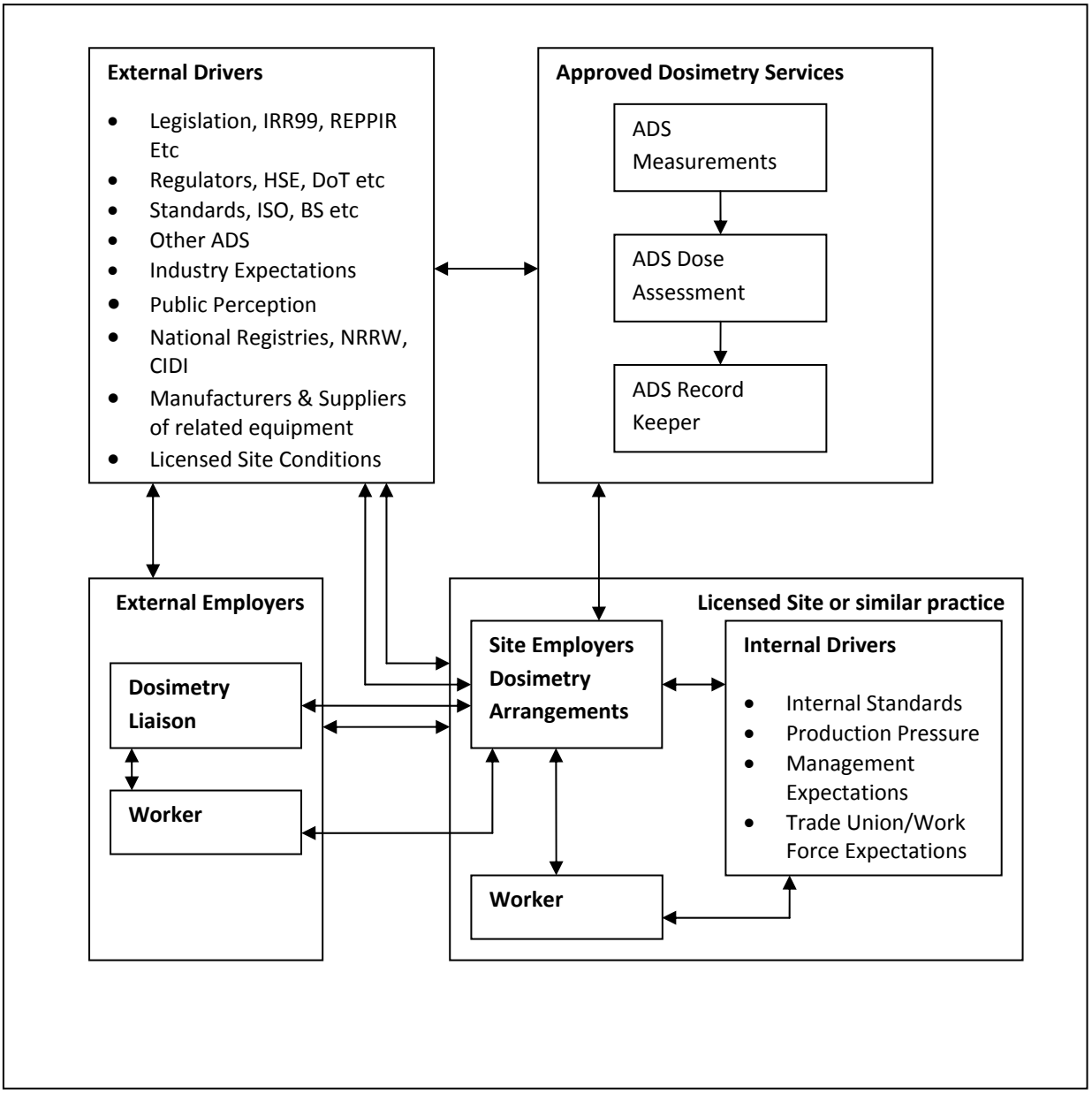

Figure 1: Dosimetry Drivers and Interfaces

1.1. Scope

This Good Practice Guide (GPG) details the principles and practices that are considered to be nuclear industry good practice with regards to personal dosimetry management and dosimetry provision to the site employer. It describes the various aspects of good practice including systems, processes and arrangements.

It is not and should not be read as a code of practice, it solely provides a reference that can be utilised by nuclear industry practitioners and site employers representatives when instigating or updating their dosimetry management processes and practices.

1.2. Application

This GPG is directly applicable to the design, development and implementation of nuclear site dosimetry management and provision. This GPG will be of use to site employer's duty holders such as:

- Radiation Protection Advisers
- Health Physicists
- Dosimetry Staff

This Guide may interest other groups, for example Health Physics Staff, external employers representatives, etc.

The issue of this GPG is not intended to initiate wholesale review of existing arrangements where there is no other driver to do so.

2. LEGAL AND OTHER DRIVERS

The legal requirements and drivers related to dosimetry management are detailed mainly within the Ionising Radiations Regulations 1999 (IRR99) [2] and The Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR) [3, 7]. In addition there are a number of other dosimetry related drivers such as international, national and business standards and recommendations, requirements related to plant safety cases, risk assessments and business requirements. All of which are also covered by the general duty of care contained within Common Law. The site employer related requirements and drivers are summarised within the sections of this chapter.

2.1. Ionising Radiations Regulations 1999

The IRR99 requirements and drivers related to dosimetry management are listed in detail at Annex 2. It is noted that a large proportion of the regulations within IRR99 directly require or imply dosimetry management responsibilities such as: Classified persons must have dosimetry provided from an HSE Approved Dosimetry Service (ADS), non classified workers doses must be estimated, records have to be maintained, results reported, investigations conducted, emergency arrangements provided, etc. Where the employers duties fall is summarised at Table 1.

Table 1: Dosimetry Duties on Employers under IRR99 [2]

Duty holder	Relevant Regulations
Any employer	4, 8, 11, 14, 15, 20 to 24 &26
Radiation employer	As above plus 7, 12, 13, 18 & 25, 34 & 35
Employer in charge of or who designates an area	16, 18 and 19
Employers in control of equipment	32
Manufacturer, supplier or installer of equipment	31
Nuclear Site License Holder	All of the above

2.2. Radiation Accident and Emergency Legislation

There is a clear distinction made between emergency exposure under REPPIR and radiation accident exposure detailed within IRR99 Regulation 23. REPPIR regulation 14 is not concerned with doses received by employees who may be exposed to ionising radiation as the result of the radiation accident that leads to a radiation emergency. Such doses are subject to the requirement of IRR99 regulation 23, see section 6.14 for radiation accident and REPPIR dosimetry management arrangements.

IRR99 Regulations 12(1), 12(2b) and 23: Where an assessment shows that a radiation accident is reasonably foreseeable the radiation employer shall prepare contingency plans to restrict the exposure to ionising radiations to those who may be effected by such an accident. A key component of monitoring this is by analysis of personal dose data. Part of these plans shall include issue of appropriate

dosemeters supplied by an ADS approved for issue of special accident dosimetry capable of recording the dose predicted within a radiation accident or other foreseeable overexposure.

REPPIR (The Radiation (Emergency Preparedness and Public Information) Regulations 2001 Regulation 14, 15 are concerned with doses received by intervention personnel once a radiation emergency has been declared an "Off-site Nuclear Emergency". Intervention personnel must only be allowed to receive emergency exposures in excess of the limits detailed within the IRR99 for the purpose's of saving life, helping endangered people, preventing large numbers of people from being exposed to ionising radiation, or saving valuable installations or goods. The site employer shall:

- have carried out a suitable hazard identification and risk evaluation to estimate the magnitude of likely doses for personnel in various functions and submitted these dose levels in advance to the Executive
- prepare emergency plans including dosimetry arrangements
- ensure intervention personnel are issued suitable means of dose monitoring to restrict personal doses, and dose assessment as part of an ADS system
- ensure dose records are made and kept by an ADS for intervention personnel issued with dosimetry as part of the emergency plan

In addition the site employer has to make arrangements for the assessment and recording of intervention doses with an ADS which has specific REPPIR approval. A REPPIR approved ADS will have met specific (Category A) performance standards. The site employer when appointing a REPPIR ADS will need to supply details of the anticipated emergency dose levels notified to the HSE.

2.3. Soft Drivers

The pressures and expectations of management, work force, the general public and pressure groups should not be ignored or discounted. Often the expectations of dosimetry measurement, assessment, record keeping and reporting are in excess of those required by legislation or international standards. Failure to address these expectations can be detrimental to an site employer, practice or organisation.

2.4. Other Drivers

Other legislative drivers related to dosimetry management and related site employers responsibilities include:

- Nuclear Installations Act 1965, in particular the related Licensed Site Condition 18
- The Carriage of Dangerous Goods etc Regulations 2009 and related European Agreement concerning Carriage of Dangerous Goods by Road (ADR)

RADS: Requirements for the approval of dosimetry services by the HSE. In order to obtain approval under IRR99 and REPPIR, a dosimetry service must be able to meet certain criteria specified by HSE. These criteria are set out in the RADS documents, made up of a number of documents covering general requirements, external dosimetry, internal dosimetry, record keeping and a supplement related to emergency exposure. Although directed towards the ADS the site employer will be affected by and will have to meet at least some of the requirements. The ADS will advise its customers of the related requirements.

Standards and Recommendations. There are a significant number of standards and recommendations both national and international that set requirements on dosimetry implementation and management. Site employers will be required by regulators, customers and their own wish to meet good practice to follow and meet these various standards. Of particular interest:

- Various International Standards Organisation (ISO) standards [16 - 27] including**:**
  - ISO 4037 series and ISO 14146 - related to dosemeter calibration
  - ISO 9000 related to quality management
  - ISO 17025 General requirements for the competence of testing and calibration laboratories
  - ISO 27048 and 27218 draft documents related to internal dosimetry
- European Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation - Radiation Protection No 160: which recommend many sensible approaches for dosimetry management. This report was prepared for the European Union by the EURADOS group
- HSE, Research Report 385 - Adequacy of external dosimetry methods and suitability of personal dosemeters for workplace radiation fields

Business Quality Requirements: It is considered good practice for any large organisation to carefully document its arrangements and business processes. This means that it is considered good practice for the dosimetry management arrangements to be clearly and simply documented meeting the relevant business standards.

External Accreditation: It is considered good practice for part or all of the dose measurement regime to be subject to accreditation by external bodies such as UKAS or similar accreditation organisations. For instance calibration of personal dosemeters, internal dose analysis regimes etc.

Data Protection: It is a requirement, under 'The Data Protection Act 1998' and 'The Computer Misuse Act (1990)' that obtaining, recording, holding and using information or data is:

- only held for legitimate reasons
- adequate but no more so than required for legitimate purposes.
- accessible to individuals if they wish to inspect data about themselves
- collected systematically and is verified
- only kept for a 'reasonable' period
- maintained such that integrity of the system maintains confidentially and security of data

Compensation Scheme: is a joint initiative between some nuclear industry employers and the relevant trade unions providing a means of resolving claims without the need for court action. Claimant's dose records and histories are compiled according to procedures agreed by the employers and the unions and include a number of generosities over and above the statutory legal record, so that the Scheme is more generous in it's assessment of cases than a court would probably be. See section 3.7.7.

Note: due to the possible implications and requirements related to potential litigation claims it is considered good practice for employers not within the scheme to maintain records in a similar manner.

National Registers: Bodies such as the National Register of Radiation Workers (NRRW) and Central Index of Dose Information (CIDI) will set requirements on the employer either directly or via the ADS. See chapter 6.

Interfaces: The site employer will interact with different bodies at different levels, for example suppliers and manufacturers, an accreditation body, an approval authority, customers both to supply personal dosemeters and dose reports and to exchange information, see Figure 1.

3. DOSIMETRY PROVISION - GENERAL REQUIREMENTS

This chapter addresses the general dosimetry provision requirements that a site employer needs to consider and potentially put in place to meet the many and varied drivers as described at chapter 2 and particularly Figure 1. It is recognised that the requirements to meet these drivers may place extensive demand and cost on the site employer.

This Guide aims to describe the provision of dosimetry services and management from the perspective of the nuclear industry radiation employer responsibilities with regards to establishing, meeting and providing the site employers dosimetry arrangements. The site has culpability for work with Ionising Radiation undertaken by all employee types, although would not assume all the radiation employer duties unless these are agreed by prior co-operation. The provision and capability of any dosimetry arrangements will reflect its requirement to satisfy legal demands, the actual and potential hazards from Ionising Radiations and appropriate good practice. Arrangements increasingly would be fluid in response to organisational and operational change. Many of the systems described in this Guide identify good practice to reflect the risk and levels of control that must be made available to address the restriction of exposure. It is considered good practice for Audits on the adequacy of the dosimetry arrangements to be carried out at suitable intervals.

In general, the choice of a suitable dosimetry system and associated measurement methodology, by a site employer, shall be made in consultation with the relevant RPA and where relevant with health physics staff, management and the workforce. The technical information on the performance characteristics of the dosimetry system should be provided by the service providers and related equipment supplier or manufacturer. It is suggested that the consultation includes discussions of the characteristics of the radiation fields in the workplaces, the most appropriate measurement arrangements, dosemeter wear position, issue period, sample regime/techniques, etc.

This chapter describes the general principles applied to dosimetry management and provides links to the other chapters by covering the following broad categories:

- Use of Hazard Assessment to determine requirements
- Requirements for a monitoring programme
- Personal Dose Monitoring Process
- Software requirements
- Dosimetry provision
- Outside Employers Arrangements
- ADS requirements

Note: the dosimetry arrangements are normally met by the site employer establishing one or more offices, with any number of staff located in a number of locations, but are referred to within this Guide in the singular as the site employer or site employer's arrangements.

3.1. Hazard Assessment, Characterisation and Significant Dose

One of the precursors to development or review of any monitoring programme will include, as required by IRR99 regulation 7, an assessment or re-assessment of the workplace radiation fields and contaminates, particularly if there is the possibility of significant doses, see below.

For external radiation exposure, as a minimum, knowledge is needed of the location, type and size of sources, the amount of shielding and scattering material. The fields will usually comprise direct and scattered components resulting in broad energy and direction distributions. For internal radiation exposure knowledge of the sources and levels of potential contaminates, routes of entry to the body, exposure periods etc.

In some instances, however, simple procedures can be used, for example to identify areas where there is a strong low energy component of external radiation which may lie below the threshold of a particular personal dosemeter type. Knowledge of workplace fields and contaminates (that is, data on energy and direction distributions, dose rates, worker orientation, occupancy factors, protection methods, survey results, environmental conditions, levels of loose contamination), can:

- be done by a combination of measurements and calculations, or by measurements alone, the measurements need not be too elaborate
- require consultation with relevant RPA and Health Physics professionals
- including the critical examination by the installer or erector of an article for use for work with ionising radiation
- examination of related radiological risk assessments
- compare to experience at other similar sites, 'do not reinvent the wheel', if the work is already done for another area or site review of that data may meet most of these requirements
- be used to select the suitable types of personal dose measurement methodology and suitable work place correction values
- contribute to the estimation of the overall uncertainty of measurement
- allow an assessment to be made of the adequacy of the use of the operational quantities as surrogates for the protection quantity
- where appropriate, allow a better estimate to be made of the protection quantity
- optimise the design of dosemeters and sample techniques
- frame the dose measurement and assessment performance requirements sensibly
- assist the retrospective interpretation of dose readings if required

These factors are discussed in greater detail at chapters 4 and 5.

3.1.1. Significant Dose

IRR99 ACOP 20(3) states that '*Exposure is significant if the employee is likely to receive an effective dose at a rate exceeding 1mSv per year'*. IRR99 Guidance para 386 also defines a significant component of dose may be significant if it exceeds 1 mSv/y, for example dose from neutrons or committed dose from internal radiation.

3.2. Requirements for a Monitoring Programme

It is a requirement that systematic individual monitoring shall be performed for classified persons where their exposure is likely to be significant, namely greater than 1mSv/y. Although not a legal requirement, it is considered good practice for personal dosimetry to be provided for non-classified workers.

If dose assessments are made for exposures to external gamma radiation or X-ray, the employer may have to decide whether additional components of dose should be assessed as well. These components may include doses such as neutron or committed dose from internal radiation. The employer will need to establish whether the component is significant or not, IRR99 ACOP para 386 gives guidance that such components should be considered significant if they exceed 1mSv/y, recognising that it may not always be appropriate to assess particular components by individual monitoring, although where practical it is considered good practice.

Monitoring of individuals occupationally exposed to ionising radiation is conducted so as to:

- demonstrate control of occupational exposure
- manage accident and emergency dosimetry arrangements (see section 6.14)
- establish whether an individual needs to be classified
- ensure and demonstrate that relevant legislative requirements are met
- demonstrate compliance with limits and constraints
- help demonstrate application and effectiveness of the ALARP principle
- inform workers of their radiation exposure
- support dose management as required for pregnant and breast-feeding employees
- inform managers, radiation protection staff, production staff, workforce representatives, regulators and others of doses received individually and collectively
- support Safety Case generation and review
- support epidemiological investigations of the effects of radiation
- to safeguard the interests of both employees and employers in the event of compensation claims

The choice of appropriate monitoring programme and the choice of suitable dosemeter/sampling regimes are at the heart of any dosimetry system, see chapter 8 for a detailed summary of good practice related to these areas.

3.3. Dosimetry System Review

The site employer should undertake and document an initial assessment of the site dosimetry requirements. This assessment should be reviewed periodically and prior to any significant change to site practices, related radiological hazard assessments or introduction of new practices. This process should include consultation with the site RPA and health physics staff. Providing the site employer's sources, workplace radiation fields and methods of work do not change significantly it is unlikely that there will be a requirement to change the dosimetry systems in use, providing they can still be shown to meet legal requirements and meet the site employer's expectations.

As part of the review the site employer should establish the technical and dosimetry suitability of the existing system and any possible alternatives. To establish the alternatives the site employer should research and list the viable and suitable systems available that can match the requirements identified within the characterisation assessment or review detailed above.

A dosimetry review may aim to establish only that the existing dosimetry system remains suitable for current and new work, rather than review the suitability of all available dosimetry systems. Less frequently, a site employer may need to consider the introduction of a new type of dosemeter or dosimetry system, for the site, perhaps as result of starting new work with radiation sources, or the need for additional functionality such as access control, or to phase-out an old system that is becoming unsupportable. In this latter case the review needs to be broader and may aim to review the suitability of all available dosimetry systems. Such a review should include a list of possible ADS or other supplier's solutions showing:

- Data as described at Annex 5
- Type test data
- ADS Statement of Service (SoS)
- Physical and dosimetry suitability
- Supplementary features and functionality
- Required administrative arrangements, e.g. how is key data transferred, entered onto system, generally managed etc

The greater detail available will assist in the suitability assessment. However, the criteria and standards used by ADS's and manufacturers to describe the characteristics and performance of their systems can vary such that it remains difficult for the site employer to assess the suitability of the various systems. It will generally be necessary to have a detailed, documented technical dialogue with the potential suppliers. Additionally, it is good practice to conduct trials of the system within the particular workplace. The process of determining the suitability of the dosemeters and related systems in relation to the site employer's workplace characterisation can be highly technical and may require support or consultation with dosimetry specialists.

3.4. Medical Exposures

Any radiation dose received by employees from medical exposures such as x-rays, nuclear medicine or CT scans should not be entered in to an individual's Dose Record or Dose History as these records are intended to only cover occupational exposures.

Where an individual worker has been injected or implanted with a radioactive isotope for clinical or medical reasons good practice is for them to report the details to their employer and the site employer. The relevant employer should make arrangements so that any radiation issues or related monitoring issues are managed and recorded. This is mainly due to the fact that they may still be emitting radiation that could affect:

- the ability to monitor them for contamination
- their personal issue Dosemeter
- other employee's dosimetry and monitoring arrangements.

Advice may need to be sought from the Appointed Doctor or RPA.

3.5. Personal Dose Monitoring Process

It is normally understood that the purpose of a Dosimetry System is to conduct personal dose measurements and to contribute to the evaluation of the results, with additional information provided by a customer or a third party. Personal dose monitoring can be broken down into five stages, namely [14]:

- make measurement
- assess dose
- evaluate dose
- record dose
- report dose

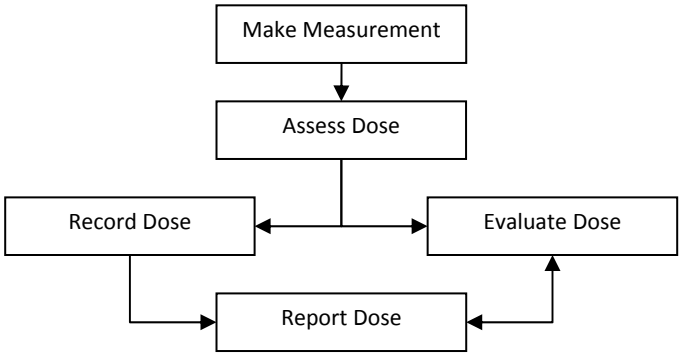

Figure 2: Personal Dose Monitoring Protocol

This section briefly looks at each stage. In practice these individual functions often overlap, coincide or run in different orders, see Figure 2 which shows some of the varying pathways. For classified persons most parts of the process have to be completed by an ADS. Later sections and chapters deal with these matters in greater detail.

3.5.1. Make Measurement

This relates to tasks such as issuing and reading personal dosemeters or conducting measurements of internal radiation or measurements of excretory contamination. The making of measurements is normally understood to be by the provision of a suitable dosimetry system (see chapter 6), appropriately tested and calibrated, in accordance with quality assurance procedures. In all cases, everybody using the data provided by the service should be aware of the uncertainty of the data and/or that the validity of the data applied to specified circumstances. The process requires detailed and careful management to ensure all key information is captured. The arrangements are covered at Chapters 4 and 5.

3.5.2. Assess Dose

One or more organisation may be responsible for the calculation of the dose, for classified persons the organisation will be part of one or more ADS. The process will require an extensive number of assumptions and referral to various national and international models. Often when an organisation has a large numbers of assessments to conduct the organisation will utilise generic assumptions related to the majority of their customer's circumstances and requirements,

these may not always be valid for the site or particular circumstance. The site employer will need to have detailed knowledge of the assumptions used by the organisation conducting the assessment and ensure that they have communicated the specific site requirements or make allowance for these assumptions. The details and arrangements are covered at Chapters 4, and 5.

3.5.3. Evaluate Dose

Generally, an organisation, such as an external ADS, has the function of delivering the results of dose measurement and assessment. Evaluation of the dose and subsequent dose control falls to the employer. This responsibility for dose evaluation is an important, but infrequently mentioned matter in radiation protection practice. Part of the site employer's organisation should be responsible for evaluation and validation of dosimetry results using information from the work place as well as the measuring and assessing organisations. Dosimetry results cannot be validated without information on the specific conditions of the dose measurement and working conditions, so close liaison between dosimetry staff and operational staff, managers, RPA's and health physics staff is important.

It is noted that in the ideal world the evaluation of dose will precede recording the dose, however due to the requirements of the ADS the site employers' evaluation may not occur until after the dose has been legally recorded. It is recommended that in such cases the site employer conducts a rigorous evaluation of the dose, advising the ADS of any unexpected results or anomalies. These evaluations may involve both the site employer and external employers. Also there may be difficulties in changing or updating doses once they are recorded as a legal dose. The details and arrangements of dose evaluation are covered at Chapters 4, 5 and 6.

3.5.4. Record Dose

Once a dose is assessed and preferably evaluated, it is recorded. For classified persons IRR99 requires that this dose is recorded and maintained by an ADS. The record of dose may be held by more than one ADS and/or employers dosimetry arrangements. If care and detailed control is not utilised, errors and miscalculations will occur. For instance, an outside worker employed at a nuclear site may have doses held, related to work on the site, by the site employer, by a number of external ADS and external employers. Each ADS and employer are liable to use the dose values held for various and differing reasons. The various employers and each ADS need to be clear as to which record relates to the legal record for personal dose control purposes and reporting purposes. Also where more than one method is utilised to assess dose, such as passive and electronic dosimetry used for whole body external radiation doses, the various site employer's, ADS and outside employer need to be clear which doses are estimates and which doses represent the legal dose and also to ensure 'double dipping' does not occur.

NOTE: to support UK compensation scheme or potential litigation requirements it is considered good practice that all personal dose records should be kept indefinitely. The details and arrangements of dose record keeping are covered at Chapter 6.

3.5.5. Report Dose

Once a dose assessment has been completed, verified and recorded the results need to be communicated to the various interested parties: these include the individual, the site employer's

management, radiation protection professionals and other relevant parties. In addition combined doses of various individuals will be accumulated to provide collective dose values to support management controls and tracking. The results of individual monitoring may be used for initiating a certain action when a predefined dose level, an action or reference level, has been exceeded. The most common forms of action/reference levels of interest in radiation protection programmes are recording levels, reporting levels, investigation levels and intervention levels. The details and arrangements are covered at Chapter 6.

3.6. Dosimetry System Software

In modern instruments the software has become of increasing importance for the generation of the measured value. Therefore, it is recommended that the final version of the dosimetry software be part of any testing regime, such as type testing. The site employer, manufacturers and suppliers should be aware of the fact that any change of the software may question the validity of the measured values.

Reference 14: the Technical Recommendations for Monitoring Individuals Occupationally Exposed to External radiation suggest that the site employer be guided by the European Legal Cooperation in Legal Metrology (WELMEC) software guide. These guidance requirements prevent any unintended modification of the software and the data. The requirements for active, direct reading instruments are based on those given by the guide for instruments with embedded software in a 'built-for-purpose measuring instrument', and for passive instruments on those given for 'systems suitable also for other purposes in addition to the purposes for which it is intended. European guideline WELMEC 7.2 - Software Guide (Measuring Instruments Directive 2004/22/EC)' contains requirements and validation recommendations for software in measuring instruments subject to regulations in the Measuring Instruments Directive. The definition of software requirements is derived from essential requirements and is based on type-independent configurations of instruments and on risk classes.

3.7. Site Employers Dosimetry Arrangements

The site employers dosimetry arrangements are normally met by the site employer establishing one or more offices, with any number of staff located in a number of locations, but are referred to within this Guide in the singular as the site employer or site employer's arrangements.

The roles and responsibilities will be included within detailed written instructions and requirements which will include the majority of the items listed below, which are all detailed in greater depth within later chapters:

3.7.1. On-Site Dose Control

On site dose control is a key element of the tasking of the site employer and will usually involve use of specialist software and personal monitoring arrangements including electronic dosemeters. Many of the issues have been or will be included within this wider chapter, but include:

- **Dosimetry Suitability**: Ensure dosimetry arrangements are suitable for radiation and contamination within all areas including those external sites where the site employers staff may enter radiological areas

- **Control Personal Doses**: Ensure personal doses are within limits and constraints, investigating and following up as necessary
- **Site Record Keeping**: including archiving and retention of site dose data, instructions, procedures, assessments, reviews and other records related to the site
- **National Registers**: The site employer will be involved, often via the ADS, with supporting national registers such as the National Register of Radiation Workers (NRRW) and Central Index of Dose Information (CIDI)
- **Outside Workers**: dealing with and managing outside employers and their employee's dose control, establishing close liaison with the other employer's dosimetry staff. Advising on the site dosimetry arrangements, requirements and suitability of other employers dosimetry for use onsite
- **Radiation Passbooks**: Managing and control employees and outside workers radiation passbooks. This will include regular update and regular liaison with external employers dosimetry staff to ensure the passbooks are updated
- **Support:** to Management, Medical Staff, Trade Unions and Workforce in dosimetry matters as required
- **Trade Unions and other Interested Groups**: The site employers dosimetry arrangements will need to support and communicate with Trade Union and other representatives to track doses and understand dose related issues
- **Liaison with Individuals**: In addition to the above, arrangements need to be put in place to provide counselling and support to workers with concerns related to work with radiation and their own actual exposure. All radiation workers should be allowed access to their records and be given copies of their records upon any reasonable request
- **Dosimetry Information Management**: arrangements should ensure that software meets the requirements and key personal records are maintained and retained in accordance with section 3.6 and chapter 6
- **Confidentiality:** All dosimetry data and data related to personnel have to be treated in the strictest confidence. Only those with a reason to review the dosimetry data should be permitted access to the information. Access should be restricted to the specific data required to meet the specific needs
- **Collective Dose**: tracking, managing and recording collective dose including task and site doses, see chapter 7
- **Error management:** Where an assessed dose exceeds a relevant dose limit or investigation level, the site employer will need to conduct an investigation or review, possibly in conjunction with the ADS and relevant RPA. This should look at the methodology, the characteristics of the methodology, and the characteristics of the workplace field. These will be used in any reassessment to provide the best estimate of effective dose

3.7.2. Off-Site Dose Control

On occasion site employees will be required to work offsite within the controlled areas of an external employer. Before travel commences arrangements should be agreed between the site employer and the employer of the site being visited. These arrangements may include risk assessment, RPA advice and agreement with regard to the dosimetry to be used for control and assessment. Arrangements differ depending upon whether the individual is visiting a UK or European Union (EU) country compared to non EU countries, see section 6.7 for more detail.

3.7.3. Pregnant and Breast- Feeding Employees

All female employees who may undertake work with ionising radiation should notify their employer in writing at the earliest practicable opportunity after they become aware that they are pregnant. This notification should be treated as in confidence.

IRR99 Regulation 8 and Management of Health and Safety at Work Regulations 1999 require for a risk assessment to be prepared in consultation with the RPA to ensure that the dose to the foetus is kept as low as reasonably practicable and is unlikely to exceed 1mSv during the remainder of the pregnancy. IRR99 guidance para 141 advises '*For exposure to external radiation this dose restriction is broadly equivalent to a dose to he surface of the abdomen of a pregnant woman of about 2mSv'*. Also IRR99 guidance para 141 and 142 advise that particular care needs to be taken with regards to internal and bodily contamination by certain radionuclides which are preferentially taken up by the tissues of the placenta and foetus or are likely to become concentrated in breast milk. In such cases it is likely that the dose to the foetus or infant may be of greater concern than the dose to the mother. The risk assessment should review the risk to the female and foetus. The assessment described at section 3.1 for the type of work the employee undertakes should help the employer decide on these risks and dosimetry measures required, [66, 67, 68]. The assessment should also take into account the following conditions:

- The present and planned work pattern of the employee
- The levels of radiation and contamination in the employees work place
- The potential for exposure to high dose rates
- The type of nuclides being used by the employee and if they are preferentially taken up by the tissues of the placenta and foetus
- Work patterns when the employee returns to work

The employer should ensure that once the assessment has been completed, in consultation with the employee, that a copy is issued to the employee. It is considered good practice for a copy of the relevant assessment to also be placed within the employee's dose record.

Where a female returns from maternity leave to work involving unsealed sources and the assessment shows that bodily contamination is reasonably foreseeable it is advisable to assume that she is breast feeding and take appropriate action, this may include special dosimetry provision to demonstrate no significant intake is occurring.

See also section 4.3.9 re dosemeter wear positions during pregnancy,

3.7.4. Approved Dosimetry Services

This sub-section looks at the provision of an ADS from the perspective of the site employer. This subsection does not try to describe establishing or running of an ADS. It is a requirement that an employer appoint one or more ADS to provide dose record keeping, provision of radiation passbooks, dose reading and dose assessment for the employers employees appointed as classified persons. It is also considered good practice, where practical, to utilise the same service to monitor and record non-classified workers doses. It will often be appropriate for an employer to separate out the various services available from an ADS namely those described at section 3.5.

Site employers need to be aware of and take into account limitation of the ADS service provided and be wary of general assumption of suitability of dosimetry systems, methods and dosemeters. Just because an ADS is HSE approved does not mean that the ADS service will be suitable for a particular employer, process or site. The duty for ensuring suitability lies with the employer. A good ADS, manufacturer or supplier will be able and willing to provide advice with regards to suitability of their dosimetry systems, equipment and methodology. The site employer should be wary of any service that is unwilling to provide the data detailed at the earlier sections and within later chapters. The site employer needs to establish and carefully document requirements and agree these contractually.

3.7.5. External Employers Dosimetry Arrangements

The site employer should liaise with the external employer to ensure adequate dosimetry arrangements have been implemented by the external employer for their staff employed on the site. These arrangements will match many of the arrangements detailed within the proceeding section and by agreement may utilise many or all of the sites dosimetry arrangements. It is good practice for the employer to document these arrangements.

3.7.6. Visitors

Visitors, this term is not recognised within IRR99, but is commonly used within the UK nuclear industry and has varying definitions. Visitors may include members of the public, non-classified workers and classified persons. Visitors are often defined as persons entering site radiological areas for a limited period. The site employer is required to have in place documented arrangements to ensure that the requirements of IRR99 are met.

3.7.7. Compensation Scheme for Radiation Linked Diseases/Litigation

Employers that are members of the Compensation Scheme for Radiation Linked Diseases are required to establish a number of agreed protocols to deal with claims routed via the Scheme. It is considered good practice that employers retain dosimetry records indefinitely for classified and non-classified staff, so as to support the scheme and potential evidence gathering related to radiation injury litigation.

As the holders of archived records, in conjunction with the ADS (Record Keeper), investigations may need to be made to answer specific questions from the Scheme or to support responses to radiation injury litigation cases. Searching for historical and legacy information is likely to be time consuming, but is likely to be used in a legal arena to support the employer. A diligent, accurate and systematic approach should always be adopted.

Note: due to the possible implications and requirements related to potential litigation claims it is considered good practice for those employers not within the scheme to maintain records in a similar manner.

3.7.8. Additional Responsibilities

In addition a site dosimetry system and the site employer's arrangements may be involved with:

- **Access Control:** it is often the case that site dosimetry systems will be linked to security access systems or may be utilised to control access to radiological areas by one degree or another
- **Classification** : Management of classified and non-classified workers personal doses
- **Training and Indoctrination**: All staff issued with dosimetry, involved in dosimetry sampling and monitor regimes etc must be suitably trained, briefed and indoctrinated with regards to the site dosimetry arrangements, use of dosimetry equipment and who to discuss dosimetry concerns etc with

4. EXTERNAL DOSIMETRY

External dosimetry is concerned with the measurement and assessment of the external radiation dose to personnel exposed to ionising radiation such as beta, gamma, x-ray and neutron.

As described at chapters 2 and 3 Ionising Radiations Regulations, license conditions, national and international standards all require site employers to monitor, assess and evaluate external personal radiation dose. For individuals who are likely to receive an external dose greater than 1mSv per year, routine dose assessment and recording is required (IRR99 Regulation 21). It is a requirement that systematic individual monitoring be performed for classified persons, although not strictly a legal requirement, it is considered good practice for personal dosimetry to be provided for non-classified workers. Additionally, as described at section 2.2 contingency arrangements are required for measurement and assessment of special accident dosimetry and provision of dosimetry for intervention personnel as defined in REPPIR. In addition external dosimetry can provide assurance that the site arrangements and controls are adequate.

The technical and dosimetry requirements for external dosimetry should be identified from the relevant work area radiological risk assessments (IRR99 regulation 7). As described at section 3.1, as a minimum, knowledge is needed of the location, type and size of radiological sources, the amount of shielding and scattering material. The fields will usually comprise direct and scattered components resulting in broad energy and direction distributions. The choice of appropriate monitoring programme and the choice of suitable dosemeters are at the heart of any dosimetry system. This chapter aims to provide guidance on the selection and use of such external dosimetry measurements and assessment systems, combined with evaluation of results. Figure 3 summarises the approach and layout of this section.

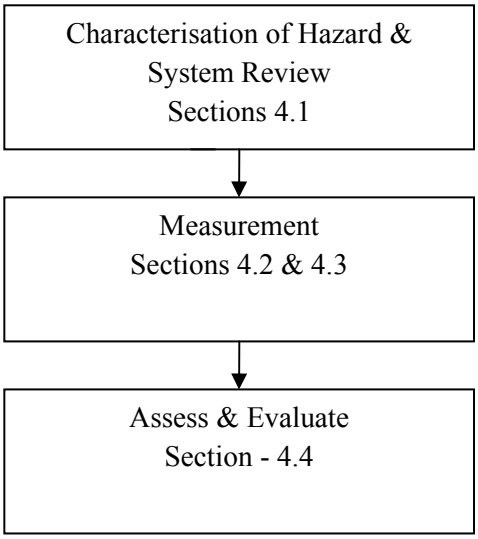

Figure 3: General Principle for External Dosimetry

4.1. Characterisation of the External Radiation Hazard

As described at section 3.1 a key part of the development or review of any external personal dose monitoring programme requirements is an assessment or re-assessment of the workplace radiological environment and risks, particularly if there is the possibility of significant external personal radiation dose. In most cases this will be part of the related various site radiological risk assessments. It is good practice for the site employer to develop a documented record of workplace radiological characterisations. Without sufficient knowledge of workplace radiological conditions no proper assessment of any dosimetry system's requirements, performance and accuracy in relation to the site employer's responsibilities is practicable.

Radiation Sources and Types: A systematic identification and documentation of all sources and types of radiation for each practice on the site is an essential component of the assessment. This should include all practices involving ionising radiations including support tasks that may be conducted on site, such as maintenance, radiography, instrument calibration, radiochemistry etc.

Measurements: unlike the laboratory conditions, in which dosemeters are calibrated, operational radiological fields will often comprise direct and scattered components resulting in broad energy and directional distributions. Determination and measurement of such fields is not always a simple matter, often requiring sophisticated measurement methods and analysis. The amount of effort to be devoted to these determinations depends very much on the particular circumstances. In many instances, there may already be information available from previous measurements or calculations, of either the actual field or similar fields. Introduction of new practices or changes to existing arrangements such as Post Operational Clean Out or Decommissioning can introduce significant changes that will require separate analysis. Also as a plant ages the radiological profile or finger print may change as shorter lived isotopes decay and longer lived, often harder to detect, isotopes come to the fore and become more dominant. Measurements to establish the energy and direction can involve use of specialist instruments such as gamma spectrometry, shield filters, shielded collimated detectors etc and may require input from dosimetry specialists. Particular examples of work done by site employers to characterise a site's workplace fields for the purpose of a dosemeter suitability assessment is given at references [59 and 60]. Use may also be made of industry compilations of useful field spectrometry data. Basic compilations of workplace photon/beta and neutron fields can be found in European Commission technical recommendation RPNo.160 [14].

Dose Rates and Time Dependence: Extreme doserates (particularly pulsed fields) can cause dose measurement and assessment issues. The site employer's radiological hazard and characterisation assessment should show whether this needs to be considered for each practice undertaken on site. The site employer should aim to quantify and document any extreme time dependence or high doserates related to personal radiation exposure onsite.

Dosimetry Data: The anticipated range of doses received by workers determines the required range of the dosemeter. These need to be assessed from existing records comparing to area surveys and predictions, establishing whether records and predictions match, explaining and documenting any significant differences.

Site Environment and Employees: The site employer will also need to include in the characterisation a summary of particular non radiological environmental and people factors that may effect dosimetry measurements on site. Such factors can include:

- Electrical Magnetic (EM) fields such as from RADAR, mobile phones, welding operations etc
- PPE worn, such as lead aprons and related dosimetry wear positions
- Localised shielding
- Naturally Occurring Radioactive Material (NORM) and other background sources, see also section 4.3.10
- Industrial work conditions, including extreme weather, wetting, extreme temperatures, under water operations, etc
- Working conditions
- Staff culture, attitude, working arrangements, general levels of literacy, language and understanding of UK/EU dosimetry requirements
- Female staff: pregnancy, new and nursing mothers etc

Foreseeable Accidents & Events: Where the assessment shows workers could receive accidental doses in excess of 500 mGy, the site employer has to consider whether 'Special Accident' dosimetry is required. Additionally, where possible intervention under REPPIR is identified specific ADS dosimetry arrangements are required. The site employer will need to consider and document the types of incident that may lead to such exposures. The most likely scenarios include criticality, high energy sources (NDE, Calibration, etc), fuel handling incidents, to name but a few. The risk assessments will need to identify the types of radiation, energy, dose rates and exposure periods, see section 6.14 for radiation accident and REPPIR dosimetry management arrangements.

4.2. External Dosimetry Measurement

The general requirements related to a dosimetry system review are detailed at section 3.3 and Annex 3. It is inappropriate in this Guide to discuss individual manufacturer's or ADS's dosimetry systems. A summary of available detection technologies, at the time of publication, showing basic physical and dosimetry properties is given within a table at Annex 5, summarised from HSE guidance [10]. This table does not illustrate extra system features such as:

- visual and audible alarms
- features which allow the dosemeter to be used for area access control
- sophisticated dose control reporting software
- combined radiation detection devices such as use of a number of detector types within a single dosemeter
- design of bespoke instruments

Dosemeters for external radiation cannot directly measure the protection quantities: effective dose (E) and tissue equivalent doses (H_T). Instead measurements are made of the personal dose equivalent operational quantities, Hp(d) such as Hp(10), Hp(0.5), Hp(0.07) and Hp(3) at standard dosemeter wear positions on the body and use these as approximations for E and H_T. These are termed the 'operational dose quantity approximations' and normally slightly overestimate the values of effective dose and tissue equivalent doses. This is described in detail within various publications from ICRP, ICRU and briefly at Annex 4.

Dosemeter manufacturers and ADS's design (D), calibrate and normalise their dosemeter to minimise the deviation of its measurement, DHp(d), from a true value, Hp(d). This aims to keep the response ratio, DHp(d) / Hp(d), as close to unity as possible over the range of radiation types (R), energies (ε),

and exposure geometries (Φ). Suppliers issue type-test data showing response graphs for standard fields and should provide more detail at the request of the site employer.

There is no perfect dosemeter, therefore the site employer must consider and assess the possibility that a dosemeter's regions of Hp(d) inaccuracy could dominate and result in unacceptable dosimetry results. International Standards detail the minimum standard for direct reading personal dose equivalent rate meters recording X, gamma and high energy beta radiation. Also The Health and Safety Executive (HSE) publish requirements for approval of dosimetry services under the regulations. These combined requirements in relation to photon response are detailed at Table 2. It is considered good practice for dosemeter measurements to aim to meet the ADS Band A requirements where practicable.

Table 2: HSE and IEC Dosemeter Radiation Measurement Criteria

	Bias	**Relative Standard Deviation**	**Remarks**
ADS Band A	<20%	<15%	Successful Performance
ADS Band B	>20% - <25%	>15% - <20%	Intermediate, Provisional Pass
ADS Band C	>25%	>=20%	Failed test
IEC 1995	<30%	NA	

If a dosemeter is marginally unsuitable for the fields that an employer is interested in, it may sometimes be improved by applying an alternative normalisation and/or calibration, achieving better approximation to the true value Hp(d). However, an employer should not expect an ADS to shift the normalisation to energies which make the dosemeter's response excessively high or low for the majority of fields for which it was originally offered as suitable by the ADS. Ideally, at least one dosemeter will be found to be adequate for all the employer's significant workplace fields. However, this may not be so and the employer may find that different worker groups exposed to different fields require different dosemeters, or that some groups exposed to a range of fields may need more than one dosemeter. The process of determining workplace correction factors can be highly technical and is an area where it is considered good practice to consult dosimetry specialists.

The site employer also needs to be aware of the suitability or otherwise of external employers supplied dosemeters for use within the sites controlled areas, see section 6.5. For instance passive badges supplied for use within medical facilities may not be suitable within a licensed sites controlled areas.

4.3. External Dosimetry Methodologies and Types

This section looks at each external dosimetry methodology and type. It does not attempt to list and detail all options but supplies a brief summary of key points and issues, looking in turn at various dosimetry methodologies and types:

- Photon and Beta Wholebody
- Neutron Wholebody
- Passive Wholebody
- Active Wholebody
- Extremity

- Accident

4.3.1. Photon and Beta Wholebody

A summary of available photon and beta detection technologies, at the time of publication, showing basic physical and dosimetry properties is given at Annex 5.

As noted within chapter 3 and 6 most sites will need to measure photon doses to provide day to day dose control and to meet the requirements to measure, assess and record classified persons radiation dose. In most cases the control measurements will be via a form of Active Personal Dosemeter (APD), linked to suitable software. There are many sites utilising ADS APD and software systems to meet both requirements. Other sites utilise a combination of APD control dosimetry with ADS passive dosimetry recording the 'legal' dose, see Annex 3.

4.3.2. Neutron Wholebody

If the effective dose to an individual from neutron radiation could exceed 1 mSv in any calendar year, then arrangements should be put in place to assess that dose. There are a number of neutron dosemeters types available, however effective detection threshold may be relatively high and suitability should be established. Typical neutron dosemeters include:

- Albedo dosemeters which can be used to measure Hp(10) from thermal neutrons and epithermal neutrons (up to a few keV) in a simple design, and with more complex configurations and response characterization and/or field specific correction factors, intermediate and high energy neutrons
- Etched-track detection (Poly Allyl Diglycol Carbonate) Chemical etching is used to enlarge neutron tracks for counting by an automated system to derive the neutron effective dose. The dosemeter responds to neutrons with energies of 200 keV and greater. The dose contribution of lower energy neutrons is calculated through the application of local correction factors. It is unaffected by X-rays and gamma radiation
- Thermoluminescent TLD detectors can be used to identify and determine the dose due to the low and intermediate energy neutrons where has been a significant neutron dose
- Combined Dosemeters, as the name implies, utilise more than one technique, such as TLD and Etched-track dosimetry to provide a more consistent response over the neutron energy range combined with ability to report beta and photon doses
- Electronic: neutron sensitive APD are available but often need very specific site correction values
- A direct reading neutron dosemeter, the bubble detector, is very sensitive to neutrons, with a detection capability of a few micro-Sieverts, and is insensitive to photons. However experience shows these to be difficult to use in operational circumstances and are considered unsuitable for use within an HSE approved service

Where neutron doses are significant, the quantitative characterisation of the workplace fields in relation to the dosemeter response functions is particularly important and may be a difficult area requiring the assistance of dosimetry specialists. More information on neutron dosemeters can be found in ICRU 66 [31].

4.3.3. Passive Wholebody Dosemeters

Passive Wholebody Dosemeters are utilised at most sites in one form or another. There is extensive experience and confidence in the use of the various passive dosemeters. However when utilised for routine dose control the delays related to reporting doses means that most sites will require to also utilise electronic control dosimetry for day to day dose management. Passive dosemeters are unaffected by pulsed fields. Detection thresholds can vary depending upon use, but for photon dosimetry can be in the region of 0.01mSv.

The issue / wear period of personal passive dosemeters will be dependant on the exposure situation and should be determined by the risk assessment and dosimetry selection process. In general terms, a short issue period would be considered where doses could be significant compared to the statutory dose limits. For classified persons the wear period is normally one month. Where doses are generally low and where the risk of a high exposure is low, then a longer issue period, typically three months, may be appropriate. Points to consider include:

- Magnitude of expected dose
- Stability of the stored image or signal on dosemeter over time
- Risk of accidental exposure, such as NDE operations
- Method of background correction, such as use of transit controls or fixed daily background deductions, see section 4.3.10
- Impact of a failed dosemeter
- Supports access control systems

4.3.4. Active Personal Dosemeters (APD)

APD can give a number of benefits to the employer, ADS, managers and employees, especially when combined with a suitable software package and the APD is calibrated to measure suitable photon qualities such as Hp(10) and Hp(0.07). These benefits can include:

- Instant indication of both accumulated dose and dose rate
- Preset visual and audible alarms
- Integrating dosemeter, linked to site control system
- Used as supplementary dosemeters to a passive dosemeter or commonly as both the control dosemeter and legal dosemeter as part of the ADS system
- Provide near immediate assessment and evaluation
- Energy and directional response characteristics of APD are, in most cases, as good as passive dosemeters, able to measure with acceptable accuracy for continuous fields, however care must be applied in presence of pulsed fields
- Provides real time short term and long term dose control and constraints against individual tasks and projects
- Ability to link real time dose information between various sites
- Telemetric dosimetry techniques
- Supports access control systems

For active dosimetry the wear period is short, normally the period the individual is within the controlled area, so if a failure of an APD does occur the impact is minimal because:,

- For many modern APD part or all of the dose will be retained within internal memory and or have been transferred to the database by a reader station or telemetric links
- If specific APD issue data is irretrievable the data lost will be minimal and may be easily estimated from other workers performing the same task or from previous similar tasks

It should however be noted that APD are not normally suitable for pulsed radiation fields.

4.3.5. Extremity Dosimetry

In cases where the dose to the extremities is likely to be significantly greater than the dose to the body or skin (as measured by the routine dosemeter), one or more extremity dosemeter should be worn to measure the dose received by the extremity, such as fingers, ankles, knees, head etc.

The guidance in IRR99 state that for whole body effective dose, a significant dose is regarded as above 1mSv and that all significant doses should be assessed. The regulations do not explicitly state what a significant dose is in terms of extremity exposure, however applying the same ratio to the limit would suggest that extremity doses typically greater than 25mSv should be assessed. It is considered good practice to set a local action level at some point lower than this to trigger an estimate of extremity dose, to ensure that all significant extremity doses are assessed.

Equivalent dose to an extremity is approximated by the equivalent dose to local skin on the extremity calibrated to measure Hp(0.07) or Hp(0.5) (Beta/Photon) or Hp(10) (neutron). Extremity dosemeters are to be worn underneath protective clothing, such as thick gloves. Where it is not possible to place the dosemeter at the most highly exposed part, such as a finger tip, experimentally derived correction factors are utilised. Various types of passive and electronic extremity dosemeters are available, including ring, finger stall and wrist dosemeters.

4.3.6. Skin Dosimetry

Doses to organs and tissues are normally averaged over their volume so as to estimate effective and equivalent dose. The main exception is the skin, where the dose equivalent to the skin from external radiation, contamination on the skin or wounds should be averaged over an area no greater than $1cm^2$[1 and 30].

For routine control purposes, personal contamination monitors at exit points from controlled areas are set to alarm at a derived limit. However if contamination cannot be removed from the skin or is initially high, further monitoring for assessment of the dose averaged over an area of $1cm^2$ may be required for comparison with the equivalent dose limit.

The guidance in IRR99 state that for whole body effective dose, a significant dose is regarded as above 1mSv and that all significant doses should be assessed. The regulations do not explicitly state what a significant dose is in terms of skin exposure, however applying the same ratio to the limit would suggest that skin doses greater than 25mSv should be assessed. It is considered good practice to set a local action level at some point lower than this to trigger an estimate of skin dose, to ensure that all significant skin doses are assessed.

There is no formal guidance on methods for calculating skin doses so the information contained in Annex 9 is based on practical experience and includes a non exhaustive list of different methods that can be used to estimate skin dose following a contamination event.

4.3.7. Eye Dosimetry

Dose to lens of the eye should be assessed in terms of the quantity Hp(3). In many circumstances it is possible to use an assessment of Hp(0.07) as a conservative estimate of eye lens dose. However, it should be borne in mind that future regulation changes are likely to result in the introduction of a much lower dose limit for eye lens, and that conservative dose assessments may not then be desirable.

Where work is in relatively uniform fields it will be possible to assess this component of dose using a dosemeter worn on the torso. Some ADS will be able to issue a single dosemeter for the assessment of whole body, eye lens and skin doses. However, if dose to the eyes could be significantly higher than that to the torso, use of an additional dosemeter will be required. Typically these are worn on the forehead (or a cap), or attached to the collar. Each site employer will need to define when additional eye lens dosemeters should be worn.

For example where any individuals are exposed to a radiation field such that the eye lens dose is likely to be 20% or more higher than that assessed by a whole body dosemeter they should be issued with an additional dosemeter worn on the forehead (or a cap) for that portion of their work where the non uniform exposure risk exists.

4.3.8. Accident Dosimetry

Where an assessment shows workers could receive accidental or intervention doses in excess of 500 mGy, the site employer has to consider whether 'Special Accident' dosimetry is required. Also where intervention is identified under REPPIR additional dosimetry arrangements may be required. Section 6.14 provides a detailed description of the radiation accident and REPPIR dosimetry management arrangements. In addition Annex 6 provides details of criticality dosimetry.

4.3.9. Dosemeter Wear Positions

Dosemeter accuracy, as described above, assumes that dosemeters are worn at predefined positions. The positioning requirements should be agreed with the ADS where relevant and form part of the dosimetry system documentation. The site employer should ensure that all wearers are correctly trained, supervised and monitored in this key aspect. For whole body dosimetry the position will normally be the front of the chest, often assisted by PPE coverall pockets, tabs etc. Other positions have been utilised for wholebody, such as waist belts.

When a female radiation worker declares she is pregnant, a risk assessment is required to be conducted, see section 3.7.3. The assessment should identify where the employee might be exposed to such an extent that her foetus would receive a dose greater than 1 mSv during a declared period of pregnancy. If the worker is to continue work within radiological areas the dosimetry arrangement should be adjusted so that the dose to the foetus is assessed and recorded, this may be by one or more dosemeters suitably positioned. These arrangements should be documented and recorded within the workers personal: dose record, section 3.7.3.

Where there is significant non-uniformity of the radiation field or where protective clothing is worn it may be necessary to use more than one dosemeter to obtain to improve the dose measurement, see Annex 3 and Annex 8.

4.3.10. Background Adjustments

It is important to understand the impact that the background radiation dose could have on the occupational photon and beta dose assessment. This is especially important when trying to determine very low occupational exposures. At the time of publication three options are utilised by the UK nuclear industry:

- No background compensation due to use of active dosemeter and lack of significant background effect
- Use of Transit Controls
- Use of fixed daily background dose per day figures

Some organisations utilise dosimetry storage / distribution boards where the personal passive dosimetry is kept until it is required to be worn within the radiological area, while others are content for staff to wear their dosemeter at all times. If a dosimetry distribution board is used in specific facilities, it is important to ensure that for passive dosimetry, the background level in that area is fully characterised. To achieve this, various techniques can be employed. The easiest method would be to place the transit control dosemeters on or adjacent to the distribution board and within postal or carried packages containing passive dosemeters, in particular where they may be exposed to x-ray security checks. The advantage to this approach is that the same type of dosemeter is used in the assessment and will respond in exactly the same manner as the personal issue dosemeters. Use of fixed daily dose per day figures is vulnerable to fluctuations in background and variations across the site and seasons.

4.4. External Dosimetry Assessment and Evaluation

The site employer should have a clear understanding of the uncertainties related to dosimetry measurement and assessment arrangements employed at their site and for their employees working at other sites. The site employer should also be able to advise external employers and their employees as to the suitability of the external employers supplied dosimetry for use on the employer's site. To achieve this, the site employer will need to liaise carefully with the ADS and external employers.

It is considered good practice for the employer to have an appreciation of how the ADS assessment uncertainty has been derived and its impact upon reported dose. Additionally the employer needs to understand and communicate to the ADS the additional uncertainties introduced from the specific site workplace and operational conditions and practices. This will become more important when employees are approaching legal limits or site constraints. See also chapter 6.

Generally, an organisation, such as an external ADS, has the function of delivering the results of dose measurement and assessment. Evaluation of the dose and subsequent dose control falls to the employer. This responsibility for dose evaluation is an important matter in radiation protection practice. Part of the site employer's organisation should be responsible for evaluation and validation of external results using information from the work place as well as the ADS. Dosimetry results cannot be validated without information on the specific conditions of the dose measurement and working conditions, so

close liaison between dosimetry staff and operational staff, managers, RPA's and health physics staff is important.

It is noted that in the ideal world the evaluation of dose will precede recording the dose, however due to the requirements of the ADS the employers' evaluation may not occur until after the dose has been legally recorded. It is recommended that in such cases the site employer conducts a rigorous evaluation of the dose, advising the ADS of any unexpected results or anomalies. These evaluations may involve both the site employer and external employers. This will often be assisted by or achieved by use of specialist dosimetry software, see chapter 6. Typically evaluation includes establishing:

- whether a significant exposure has been received
- whether any result deviates from expected values
- whether dose recorded on APD and Passive badges, worn simultaneously, correlate within excepted bands as defined within the characterisation assessment, see Annex 3
- dosemeter issued to an individual has been lost, damaged or destroyed rendering its result unusable or unreliable
- whether there is reason to believe that an issued or used Dosemeter has been exposed to significant amounts of ionising radiations whilst not being worn and prior to formal measurement/assessment
- indications of medical exposures or other inadvertent exposure of dosemeters to X-rays etc
- reasons for APD Alarms or similar indications
- whether there are unexpected significant differences between Hp(10) and Hp(0.07) assessed doses
- whether comparison to co-workers shows significant unexpected differences
- reasons and estimated doses related to ADS reported errors, omissions or dosemeter damage

5. INTERNAL DOSIMETRY

Internal Dosimetry is concerned with the intake of radioactive material into the body, its movement around the body, its clearance from the body and the dose it delivers to the various organs. Dose arising from sources of radioactivity inside the body is normally referred to as internal dose.

The Ionising Radiation Regulations require employers to monitor and assess internal dose. For individuals who are likely to receive > 1mSv per year internal dose, dose assessment and recording on the dose record is required (Regulation 21). For any event likely to give individuals a dose > 6 mSv an investigation must be carried out (Regulation 23). Monitoring and assessment as a result of the above regulations must be carried out by an Approved Dosimetry Service (ADS) with the appropriate approval for the relevant isotopes.

In addition to these legal requirements there may also be site specific issues for example operational requirements and workforce reassurance. The employer may be interested in values significantly lower than the above values where internal dose monitoring may be being used for demonstration of dose control and general effectiveness of control measures. This type of monitoring does not have to be performed by an ADS but use of an ADS or similar standards is good practice.

Internal exposure can take the form of either low level chronic intake over a protracted period which will result in a significant annual dose or an acute exposure over a single or short period of time. In both cases monitoring/assessment of dose follows the same method.

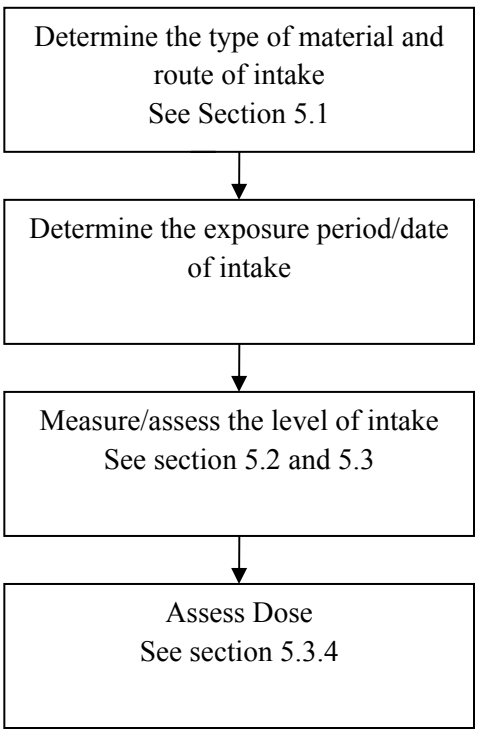

Figure 4: General Principles for Monitoring and Assessment of Internal Dose

5.1. Type of Material and Intake route

Monitoring methods should be targeted towards the radionuclide, material types found in the contamination areas and most likely intake routes. This section describes some of the parameters to consider when developing the internal monitoring program. ICRP provide default values where specific measurements are not available due to technical or cost reasons.

5.1.1. Type of Material

When performing internal dose assessments information on a range of parameters is required.

Activity Median Aerodynamic Diameter (AMAD) - AMAD is the parameter most commonly used to characterise the particle size of aerosols. A default value of 5 μm is recommended for workplace exposures, and 1 μm for environmental exposures. However, particle sizes can vary quite widely (ie. 1-20 μm) and under or over estimates by a factor of 2 are easily possible. There are therefore circumstances where a more detailed knowledge of particle size is advisable for example where annual committed effective doses are expected to exceed a value of about 5 mSv, measurement of particle size would be recommended.

In rare cases it may be possible to estimate particle size for a specific event from bioassay measurements. Generally early lung and faecal data will be required.

Lung Solubility: ICRP classifies materials according to three default types (fast, moderate and slow). ICRP68 provides recommended default types for workplace exposures. However, even more so than with AMAD, assumptions about solubility can lead to under or over estimates in dose assessments. Therefore material specific parameters are desirable in some circumstances:

- Where annual committed effective doses are expected to exceed a value of about 5 mSv, studies of solubility would be recommended so that site-specific parameters can be derived.
- ICRP is planning to publish updated guidance on solubility for some radionuclides, and where such data is available its use may be recommended in place of default parameters.
- The IDEAS guidelines [58] advise varying solubility at doses above 1 mSv if default assumptions do not give an acceptable fit to the data. These guidelines give detailed advice on the process to follow.

Isotopic composition: For both technical and cost reasons, many monitoring programme will only directly monitor some radionuclides, with dose from other radionuclides being calculated based on an established isotopic mix. There is therefore a requirement to obtain information on the isotopic mix to which a worker is exposed.

5.1.2. Pathway into the Body

There are four pathways into the body:

Ingestion is relatively unimportant in the occupational dose sense as it is easy to control. No eating, smoking or drinking is permitted in identified controlled areas and hands must be checked for contamination on leaving the area.

Inhalation: Entry of activity into the body via the lungs is by far the most significant route and a great deal of time and money is spent on the control and detection of air contamination

Wounds: Potentially a very serious pathway for the entry of activity into the body since a large amount of activity can get directly into the blood stream and hence to the various organs. Intact skin is a good barrier. Broken skin can be a problem as it cannot be scrubbed to remove contamination and individuals with skin complaints should only enter radiation areas under specific written arrangements. Small cuts and abrasions must be properly covered before entering a radiation area.

Wound probes are used to check for activity present at the wound.

Absorption: Through the skin for nuclides such as Tritium.

5.2. Measure/Assess Level of Intake

Internal exposure cannot be measured directly and is normally assessed by indirect means via one or more methods.

5.2.1. In Vivo Monitoring

In vivo monitoring relies on the detection of radiations escaping from the body and is therefore most suitable for the detection of medium to high energy gamma emitting radionuclides where most of the radiations emitted will escape. Low energy x ray emissions from actinides may also be used to monitor activity in certain organs/tissues of the body (eg. lung), but at low energies much of the emitted radiation will be absorbed by the body tissue, and very little will escape to reach the detectors.

Gamma and x-ray emitting isotopes each have their own characteristic energy spectrum consisting of a peak or peaks at known energies, and by examining the combination of peaks in the spectrum it is possible to identify the isotopes present. By examining the peak areas it is also possible to quantify the activity present, the larger the area, the more activity.

Limits of detection for fission products/activation products are very low when compared to the permitted annual limit on intake (ALI) and in vivo monitoring is one of the ICRP recommended technique for dose assessment for these isotopes. Limits of detection for the lower energy gamma and x-ray emitters (e.g. plutonium, americium) are high and in vivo monitoring is unsuitable for detecting small acute intakes or for the routine monitoring of on going low level chronic exposure. However, if a reliable beta gamma to alpha ratio is available, the result from in vivo fission product measurement can be used to infer the probable intake of alpha emitters where exposure is to a mixture of gamma emitting fission products and alpha emitters

When performing whole body monitors it is important that individuals shower and change clothing prior to any measurement. Any body surface contamination on the individual would result in a significant over estimate of intake from the whole body monitor measurement as all activity measured is assumed to be inside the body.

For lower energy gamma and x ray emitters chest wall thickness becomes very important. As part of the assessment this parameter should be taken into account. There are a number of

methods of determining this factor and include using weight:height ratios and ultrascan measurements.

5.2.2. Bio Sampling - Urine

Routine urine sampling can be undertaken to assess chronic low level exposure of individuals during their normal work. This form of monitoring consists of provision of samples at a fixed frequency throughout the period of employment or following involvement in specific tasks where there is potential for exposure.

Samples of urine are also requested following suspected abnormal exposures. In such cases a series of samples is usually requested and these are individually analysed for the radionuclide of interest.

Monitoring Frequency: The monitoring frequency is determined essentially by the combination of the rate at which the material is eliminated from the body and the radioactive half life of the particular radionuclide. For example tritium, although its radioactive half life is relatively long, is rapidly cleared from the human body, so a weekly or bi weekly monitoring frequency is appropriate for tritium. On the other hand for very tenaciously retained, long lived radionuclides like plutonium, for monitoring of chronic exposure an annual sampling period may be adequate because of the very protracted nature of the urinary excretion. Other radionuclides such as uranium, which lie somewhere in between, may require a more frequent sampling for example monthly. For acute intakes it is important to collect samples close to the event, ideally within a few days.

Sample Volume: In addition to the frequency of monitoring some consideration must also be given to the volume of urine supplied at each monitoring interval. The reasons for this are two fold:

- Firstly, provision of a large sample volume will help to average out daily variations in the individuals metabolism giving a better estimate of the chronic excretion rate
- Secondly, a large volume of urine for chemical analysis improves the effective limit of detection

Sample Normalisation (daily excretion rate): The quantity normally used in conjunction with biokinetic models for assessment of intake is the daily excretion rate. Ideally 24 hour samples should be taken but as this is generally impracticable, fixed volume samples can be taken and normalised to daily excretion rate. The International Commission for Radiological Protection (ICRP) have published guidance on standard criteria for 'reference man'. This information can be used to normalise samples to daily excretion rates. The latest publication is ICRP 89 but many ADS and employers are still using the previous ICRP 23. ICRP 89 states that on average men excrete 1.6 litres of urine per day and women 1.2 l/day(ICRP 23– 1.4 litres/day for both men and women), but the daily volume of urinary excretion is quite variable. A more reliable method of sample normalisation is on the basis of creatinine content of the sample. Creatinine is a biological breakdown product of muscle metabolism which can be readily measured in the urine and the rate of creatinine excretion in humans remains fairly constant at about 1.7 g/day for males and 1.0 g/day for females(both ICRP89 and ICRP23)

Containers: Suitable bottles and provision locations should be provided for the users. Suitable storage arrangements should be provided ensuring samples are protected from cross contamination, loss, direct sunlight etc. The bottles should be large enough for the volume of urine required, have a secure, leak tight cap or lid, should be able to withstand being accidentally dropped and have a sufficiently wide neck to facilitate sample provision. The bottles should also be suitably labelled to ensure they uniquely identify the provider.

5.2.3. Bio Sampling: Faecal

Faecal monitoring is an unpopular technique for those who are requested to provide samples, and as a consequence it is usually restricted to the investigation of suspected abnormal exposures. However, it is the only monitoring technique that can detect small intakes for some materials such as Plutonium oxide.

Analysis of promptly provided faecal samples can give invaluable information about acute inhalation exposures because a large proportion of activity initially deposited in the lung is cleared via the GI tract in the first few days following exposure.

A series of faecal samples is usually requested for dosimetry investigation. These samples are analysed individually to monitor the time dependence of clearance from the lungs.

Sampling Period: Samples can either be collected as 24 hour samples to give daily excretion but where this is impracticable a single voiding can be normalised by weight to the ICRP 89 recommended values of 150g/day for men and 120 g/day for women (ICRP 23 - 135 g/day for men and 110 g/day for women). Minimum sample size should be at least 50 grammes to give a reasonable limit of detection. It is important to note that very small intakes close to provision of faecal samples can result in a significant over estimate of intake. Ideally faecal samples should be provided after a period of non active work or following an event the individual is removed from active work until after they have completed their samples.

Containers: Suitable pots and provision locations should be provided for the users. The pots should be large enough for the sample required, have a secure cap or lid, should be able to withstand being accidentally dropped and have a sufficiently wide neck to facilitate sample provision. Provision of a plastic bag within a pot is probably best. This enables the analysis labs to easily remove the sample from the pot for analysis. The bag is usually ashed with the sample and therefore a plastic bag type should be agreed with the labs prior to sample analysis being required. The pots should also be suitably labelled to ensure they uniquely identify the provider. Provision of a freezer to store samples prior to dispatch to the laboratory is also recommended.

5.2.4. Bio Sampling: General Advice

Provision dates: To ensure dose assessment it is very important to accurately record the date or dates of provision of biological samples. For services where there are a large number of samples provided by its workers a bar-coded labelling system which in conjunction with a barcode reader can be used to record dates when samples are issued and returned is recommended. For smaller services a paper system is probably sufficient.

Sample provision: Precautions should be taken to ensure that inadvertent sample contamination doesn't happen. Very small levels of un-metabolised material in the sample will

result in a significant over assessment of intake. Therefore washing facilities and personal monitoring should be provided prior to sample provision.

Samples should be provided/collected promptly preferably within a few days of any suspected internal intake. Where a series of samples are requested to record changes in excretion rates over a period of time the individual should be advised not to provide all samples on a single day. Individuals should also be advised not to drink excess amounts of fluids to increase excretion rate, unless part of post intake dose reduction intervention, e.g. tritium intake.

Nose blows/nasal swabs: Samples of activity deposited in the nose after abnormal inhalation exposures can be taken either by blowing into a tissue or by taking swabs of the nasal cavities. These samples can then be counted in a dedicated, pre calibrated counter. Although there has been some work carried out on nose blowing and swabbing which allows the assessment of intakes from measured activities, the potential uncertainties are such that nose blows and swabs are most suitable as a rapid screening technique prior to further investigation using urine sampling, faecal sampling and in vivo monitoring.

Blood/Body Tissue Sampling: The measurement of activity of body samples is obviously limited by the frequency and size of the samples. Blood and Biopsy samples are rarely taken and are only suitable for certain radionuclides with sufficient activities to give a reasonable limit of detection.

Assessment of activity in a blood sample following an acute exposure allows the direct quantification of activity present in the systemic circulation, but it is only suitable for isotopes of high specific activity where a small volume is required. The interpretation of the blood sample activities in terms of intake is not straightforward. The simple metabolic functions used for dose assessment purposes do not accurately reflect the short term transfer of activity to and from the blood, and more complex models must be employed.

Soft factors should also be taken into account when putting a biological sampling program in place. For example the unpleasantness of providing faecal samples should be taken into account when determining the best sampling technique. In cases where it is deemed necessary to take faecal samples then procedures should be put in place to facilitate provision for example allowing individual to provide samples at home or provision of dedicated facility for sample provision and storage on site which is convenient and provides a degree of privacy for the individual.

5.2.5. Air Sampling

Personal monitoring is ideal for the prompt measurement of some radionuclides (e.g. in vivo monitoring for Cs-137) but less so for others (e.g. Plutonium). To enable compliance with dose limits to be demonstrated for long lived long retained radionuclides alternative methods have to be employed.

Personal Air Sampling (PAS)

In those areas where potential internal exposure could exceed 1 mSv /year it is required that the site employer assess this dose. The Personal Air Sampler (PAS) is a simple device for quickly assessing the potential exposure.

They can be used in a number of ways including routine issue, campaign issue and job issue depending on the local requirements.

The PAS consists of a calibrated air pump of known capacity connected to a sampling head which incorporates a filter paper. The sampling head is clipped to the outside of the coveralls close to the individuals breathing zone. The activity on the paper can then be related to the potential intake using a ratio of the pump capacity (litres per minute) to standard mans breathing rate. As an aid for the wearer areas with significantly different ALIs should have different coloured heads. For individuals working in several PAS areas two or more PAS heads may be required with the relevant one only being worn in each area. It should be noted that PAS does not assess actual intake as an active particle on the filter paper has not entered the lungs. PAS monitoring is therefore often backed up by biological sampling/in vivo monitoring programmes. These techniques can assess the actual intake either as a suspected acute intake as indicated by the PAS or chronic exposure over the longer term.

Static Air Sampling (SAS)

If the potential for exposure and /or dose is low compliance with dose limits may be demonstrated using Static Air Samplers (SASs). The SASs should be located in all areas of plant where there is potential for personal exposure: areas which have a range of exposure potentials should have samplers positioned in each different location.

More sophisticated systems incorporating occupancy data for groups or individuals can be used for personal dose assessment. Group occupancy is sufficient for well defined work patterns with individual occupancy being used for all other areas. As with the PAS the ALIs used in the SAS calculations are plant specific. Again as with PAS, the above system may be backed up by routine biological sampling/in vivo monitoring programme on the potential for exposure.

Autoradiography of air samples

A useful tool for use on air sample filters is autoradiography. Auto radiography can be used to provide information on the composition of the activity on the filter paper. It will indicate if it is due to an aerosol or a single particle.

5.3. Determining Most Appropriate Monitoring Method

When developing an internal monitoring program it is important to include provision for both chronic and acute exposures. The following paragraphs provide some guidance on what key issues to consider and recommendations for most appropriate method.

5.3.1. Chronic Exposure

The requirement for dose assessment comes from regulation 21 IRR99 (Dose assessment and Recording). For internal dose the regulation requires that all classified persons who are likely to receive an annual dose >1 mSv committed dose need to be monitored and the dose recorded on the dose record

Actinides

- For actinides Air sampling is the only technique which is sensitive enough to measure doses at or below the 1mSv per year level. Urine samples are not sensitive enough to measure the small doses workers are routinely exposed to for Plutonium.
- Urine samples can be used to check whether there is a long term build up of radioactive material in the body
    - Plutonium is retained in the body for many years so samples provided every year or every few years are sufficient.
    - Uranium is removed from the body quicker than plutonium therefore more frequent sampling is required.
- Faecal sampling can be a sufficiently sensitive technique for insoluble materials such as plutonium oxide. However, interpretation of faecal sample results is difficult because it is generally impossible to distinguish between a small intake (of a few μSv) in the week prior to sample provision and a large intake (of several mSv) a few months prior to sample provision. Collection of more faecal samples, ideally provided whilst restricted from relevant work areas, will be required to confirm whether a new significant intake has occurred.

Fission Products

The best technique is whole body monitoring but urine sampling can be used where this facility is not readily available.

Tritium, S-35 and Sr-90: The only viable technique is urine sampling

Thorium: It is found in our natural environment and is actively concentrated by some plants. To get adequate detection limits by urine sampling, large samples (6 litres +) are required. The only sensible sampling method is faecal sampling. Pre work samples are essential to get a baseline for each individual. Excessive natural levels (eating brazil nuts for example) can usually be identified because the concentration of Th-228 is higher than would be expected as plants seem to have a preference for Ra-228.

5.3.2. Acute Exposures

Acute exposures are usually unplanned and therefore one of the key areas is detection of the event. There are a number of methods available which can be used as part of a routine screening program for individuals with potential for internal exposure. These methods include:

Post work personnel monitoring:

- Nose Blow Sampling
- Nasal swabs
- Wound Monitoring: Wound probes work in the same manner as the whole body monitor detectors.
- Facial swabs
- Hand monitors
- Frisking probes
- Exit monitors

Plant monitoring:

- Air Sampling: both alarmed and not.

Personnel monitoring:

- In Vivo Monitoring
- Biological Sampling.

Any indication of internal exposure identified by the above methods should be followed up by further investigation which may include internal monitoring.

In addition to the investigation of any event and subsequent monitoring it is important to have in place procedures to ensure engagement of occupational health department/medical officer to provide suitable counselling to reassure the individual where appropriate.

See section 6.14 for radiation accident and REPPIR dosimetry management arrangements.

Radio-nuclide	Type of monitoring	Required monitoring data[(a)]					
		D < 1 mSv		1 mSv < D < 6 mSv		D > 6 mSv	
		Number	Time range (days)	Number	Time range (days)	Number	Time range (days)
H-3	Urine	1	-	3	14	5	14
Co-60	Whole body	1	-	3	30	5	30
	Urine					3	30
Sr-90	Urine	1	-	3	30	3	30
	Faeces					3	30
I-131	Thyroid	1	-	3	7	3	7
	Urine					3	7
Cs-137	Whole body	1	-	3	90	5	90
U-235	Urine	1	-	2	30	5	60
	Faeces			2	30	3	60
	Lungs			2	30	3	60
Pu-239	Urine	n.a.	-	3	30	5	60
	Faeces			3	30	5	60
Am-241	Urine	n.a.	-	2	30	3	60
	Faeces			2	30	3	60
	Lungs			2	30	2	180
	Skeleton					2	180

(a) These measurements are desirable if facilities are available.

Figure 5: Table extracted from IDEAS Guidelines

Figure 5 shows a table copied from the IDEAS guidelines [58] which gives recommendations for numbers and type of sampling for various nuclides depending on the level of potential exposure (within the table D = Dose). In cases where there is insufficient information to

determine if the dose is likely to be < 1mSv it is best to assume dose> 1 mSv and take more than 1 sample.

5.3.3. Methods to Limit Intake Following an Exposure

Chelating Agents: Chemicals which can be administered by either injection or nebuliser, for example, Diethylene-triamine-pentaacetic acid (DTPA) which binds to Plutonium and Americium in the blood and increases the early excretion from the body. It is seen as being useful for large exposures but in each case the doctor will need to make a judgement on the relative risks and benefits before administering and therefore an estimate of the likely intake will be required.

Excision of wounds: The priority on monitoring of wounds is the early detection of activity in the wound. Whilst the decision of whether to excise, any tissue to reduce the potential for uptake into the body, is a medical decision. The doctor is likely to require an estimate of the activity present at the wound site. The doctor can then make a judgement on the relative risks and benefits on a case by case basis.

5.3.4. Reassurance

For individuals not subject to routine internal dose assessment, demonstration that they are not receiving significant internal dose is required. This type of monitoring not only provides this evidence but also provides a level of reassurance to the workforce.

It is used to demonstrate that plant controls are working, some personnel reassurance and demonstration that systematic dose assessment is not required.

While workplace monitoring is sufficient individual monitoring can be used.

Individual monitoring for reassurance does not need to be carried out by an ADS, however the site employer should be able to demonstrate that the measurements and assessments have been made to a satisfactory standard.

5.3.5. Baseline Monitoring

This type of monitoring is not a requirement of IRR99 but some site employers find it useful to have in place monitoring to baseline the individuals prior to commencing any work and/or at the completion of any work on their site particularly for itinerant workers. This would provide information for any future investigations into internal exposure but depending on the site could be expensive and practically difficult to carry out.

As above the monitoring does not need to be carried out by an ADS but again the site employer should be able to demonstrate that the measurements and assessments have been made to a satisfactory standard.

5.4. Internal Dose Assessment

Assessment of Internal dose is a specialist area and dose assessments should be carried out by an ADS or similar specialist. This section details some of the areas for uncertainty within the dose calculation and is useful for the employer to bear in mind when providing information to the ADS.

When determining the internal dose there are a number of key pieces of information which are required, including:

Bio sample/In Vivo monitoring results: Including activity and provision dates. Internal Doses are assessed using bio kinetic models. The behaviour of radioactive materials inside the body is complex and governed partly by their physical properties and partly by their biological factors. The bio kinetic models are developed by the ICRP. The models describe the movement of radioactivity around and out of the body. Using activity in either bio samples or in vivo monitoring results and these models, the amount of material which was taken into the body can be assessed. The related methodologies are detailed within the key ICRP publications, see ICRP publications listed within the References section.

Date of exposure: As explained above the date of exposure is key to determining the intake. In cases where date of exposure is not available guidance suggests using the mid point between a known date of no intake and date of first detection of event. This could be the time between 2 samples, one with no evidence of an event and the subsequent one which shows evidence of an event. However it is much better to try and identify the date as this default can lead to assessment of large doses which may be a significant over estimate.

Individual exposure history: If an individual has a history of internal exposure this needs to be taken into account. Actinides in particular stay in the body for many years(Pu biological half life = 50 years). Therefore activity is excreted from the body for many years following an intake. If previous history is not taken into account then all the activity in the current samples will be attributed to this event which will result in an overestimate

6. DOSIMETRY CONTROL

Work with ionising radiations and the establishment of Controlled Areas requires the provision of dosimetry for classified persons, a dosimetry system such as Dosimetry Software and arrangements with one or more ADS. Management systems are required to secure robust arrangements for all individuals who work with ionising radiations on the employer's site including classified persons and non-classified workers. See chapters 1, 2 and 3 in relation to general requirements for dosimetry control and related drivers. This chapter expands upon these, describing the dosimetry control arrangements that can be utilised to achieve this.

The site employer's dosimetry arrangements are established to service the needs of the site employer and employees who are exposed to ionising radiations on the site. The list below illustrates typical requirements:

- Arrangements to measure, assess and record the dose of persons entering Controlled Areas, including establishment of arrangements with an ADS
- Ensure written arrangements are in place for non-classified workers who enter Controlled Areas
- Liaison with others to ensure Medical Review for classified persons and training remain valid
- Review and update radiation passbooks
- Pass on dose and Dose Record information to other radiation employers and ADS services as applicable.
- Ensuring personal dose investigation are conducted as required, e.g. dose meter damage or lost, inaccurate dose record suspected, radiation accident or event. Advising and informing the individual of the results and recording the details within the individuals Dose Record or Dose History as appropriate
- Make the Dose Record available to the employee to whom it applies
- Where practicable ensure termination records are provided to classified persons when their employment ceases
- Reassurance, advice and support to the workforce and management.
- Provide support and dose information for epidemiological, compensation, CIDI, NRRW and dosimetry statistical stakeholders.

6.1. Dosimetry Management and Control System

The requirements for dose control systems are largely dependant upon the:

- dose rates and contamination levels found in the work environment
- tasks undertaken in usual operations
- maintenance activities
- project and tasks
- postulated radiation accident situations

Day to day personal external dose control within controlled areas with significant and variable radiation dose rates may be achieved by use of a suitable APD. Such systems have been shown to be an invaluable tool on the majority of the major nuclear sites world wide. For large sites and/or controlled areas with complex tasking, it is considered good practice for the APD issue and general dosimetry

management to include use of specialist software and hardware. There are a variety of suitable systems available. However a manual system may suffice for small and non complex sites, but such manual systems, if employed, should meet the minimal requirements detailed within this section. Where risk assessments identify potential of internal exposure dosimetry control will need to include and relate to the internal dosimetry assessment arrangements, see chapter 5.

These systems benefit from the ability to provide real time dose assessment related to individuals, tasks and specific groups and early warning of dosimetry related control issues. In some cases these systems have been extended to become part of an ADS system removing the requirement for double dosimetry (e.g. passive and APD). The systems are strengthened further when they are linked to work management and information networks, see Annex 3.

Typically these systems will include:

- specific task codes for the work which presets the APD with information such as dose rate and cumulative dose alarms
- tracking of APD issues, return and general control
- linking task codes to plant areas, work management and safety documentation
- confirmation that the issue is correct for the employee, radiation employer, work permit, location, training, medical review etc
- measures to prevent an employee from entering controlled areas where the sum of cumulative dose for the Calendar Year and task exceed a predefined dose constraint
- constraints related to previous dose alarms and other APD use issues
- ability for self issue of APD
- access control, such as specific personal identification, time limitation etc
- display of dose at point of entry
- independent notification to site employer and others of alarms, issues, failures etc
- provision of automated reports, dose/work correlations and general data manipulation
- integrated dose and dose rates for individuals supporting high dose rate or dose task control
- support and minimise dosimetry administrative burden
- real time controls and information
- ability to track itinerants who work across various site local areas or between employers and different sites
- APD management control e.g. calibration expiry dates
- material can be down loaded for incorporation into other applications and systems

Primarily this is for dose control and work allocation using external whole body dosimetry APDs. It is anticipated that this area of technology will continue to advance and develop. This guide can therefore only be a snap shot of expectations at time of publication.

In order to be part of the dosimetry arrangements staff need to be provided with suitable training related to the arrangements and systems.

There is the potential to incorporate other aspects of dosimetry or monitoring to supplement management of work and individual control within these systems. The systems also could be expanded to include biological assay assessments, plant and personal air sampler result information, area mapping or area monitoring information.

Operational dose information (day to day dosimetry control), dosemeter issue and assessment, should be structured so as to supply a range of routine dose summary and notification reports. This will where

relevant provide line managers and supervisors with dose information. It is considered good practice for the site employer to provide some added value to dose summary reports by using some common investigative and statistical methods to identify and challenge radiological protection practice.

It should be noted that the Data Protection Act (2000) requirements will apply to the dosimetry system and arrangements. The site employer will need to seek advice with regards to meeting these requirements for all aspects of data retention and transfer.

6.2. Selection of ADS Service

Chapter 3 describes the requirements to assess and appoint an ADS. The site employer has a duty to make provisions with one or more ADS to measure, assess, analyse and record its employee's external and internal exposure to ionising radiations. The site employer should seek the advice of the RPA on the adequacy and suitability of all the required services and devices used. It is considered good practice to produce written reports describing the dosimetry arrangement as a whole illustrating the suitability of the arrangements and the ADS for site operations.

For all ADS assessments a report will be provided to the employer from the ADS record keeper, however this will normally take up to 28 days to be processed and dose report issued, as contracted with the various ADS and required by RADS.

For classified persons the personal dose data is held as a Dose Record by the ADS record keeper, whilst for non classified workers these are held as a Dose History which may be maintained by either the ADS record keeper or the employer.

6.3. Dose Limits

IRR99 dose limits for employees 18 years of age or older are the same regardless of designation status, although the designation requirements noted within this chapter imply more stringent constraints for non-classified workers. The IRR99 specify lower dose limits for trainees under 18, special dose limits for women of reproductive capacity, women who have declared pregnancy and other persons, see section 3.7.3. The dose limits that apply for members of the public or other persons should equally apply to site employees that are based on the site but who do not work with ionising radiations and this is limited to 1 mSv per Calendar Year. It is considered good practice for the site employer to specify constraint levels consistent with risk assessments and historical dose.

The Safety Assessment Principles align IRR99 dose limits with basic safety limits and set a basic safety objective at 1 mSv for employees working with ionising radiations. This often forms a backdrop to establishment of site constraints, targets and performance indicators etc.

6.4. Designation of Site Employees

The designation of people who work with ionising radiation and contamination can be misunderstood. Some employees are unnecessarily designated as classified persons. Whether a worker should be designated as a classified person or non classified worker relates to the risk assessment from exposure to ionising radiations.

IRR99 and associated ACoP indicates designation as a classified person, where:

- there is likelihood that the employee will exceed an Effective Dose of 6 mSv in a Calendar Year or
- there is likelihood the employee will exceed 3/10ths of equivalent dose limits in a Calendar Year or
- works with any source of ionising radiation capable of giving rise to a dose rate liable to give a dose in excess of a legal dose limit within several minutes

Site employers should have an uncomplicated clear policy and criteria for determining the requirements for classification. For many radiation employers only a small proportion of their employee's will require to be classified. Other employees required to work or visit controlled areas may do so as non-classified workers. Examination or evaluation of historical dose statistical records of workers who perform similar work can help in determining who should be classified persons. Just because an employee spends significant time within controlled areas does not necessarily mean that that individual needs to be classified. The designation should be based upon a measured assessment of potential exposure to ionising radiation and the site employers established criteria for designation

All site employees designated as classified persons require

- Initial and annual Medical Review by an Appointed Doctor
- Formal Health Records
- Specified training
- Provision of suitable ADS personal dosimetry and dose assessment
- Dose Record maintained with an ADS
- Radiation passbook if visiting other employers areas or sites

When classifying a non classified worker it is considered good practice to ensure that any dose received as a non-classified worker within that calendar year is accounted for and advised to the ADS Record keeper.

Site employees who are designated as non-classified workers still require attentive safety oversight by the site employer to protect staff from the hazards associated with exposure to ionising radiations. Entry to Controlled Areas is undertaken by written arrangements which set out, amongst other details, how individual dose assessment will be performed. Good practice is to provide individual issue dosimetry to measure and assess employee dose, the assessed dose is recorded in a Dose History established by the site employer (usually provided by the ADS record service but not specifically). The site employer would then be able to secure its position against its performance monitoring and dose constraint programme. Likewise it would be assured when advising a site employee, an external employer or regulator of Dose History information.

The policy dealing with designation status must encompass vulnerable classes of site employees such as pregnant or breast feeding women (section 3.7.3), trainees under the age of 18.

6.5. Dosimetry Co-operation with External Employers

Co-operation between the site dosimetry staff, site managers and the external employer is fundamental to good site dosimetry management. It is good practice to ensure that the site employer's dose restriction policy applies to all external employees regardless of employer or nationality. This section details the key elements of this co-operation.

External employers classified persons will require Dosemeters which are supplied, assessed and recorded by one or more ADS appointed by the employer. This may include dosemeters and/or dosimetry assessments provided by the sites appointed ADS assessment service, providing this is agreed with the employers appointed ADS record keeper and appropriate arrangements for exchange of dosimetry information is made between the relevant ADS's. Arrangements for external non-classified workers should match those of site staff or as agreed between the employers

Where the external employer provides their own external personal dose meters to their staff or biological assay, any dose record summary supplied by the external employer may also be used to support local dose control. It is considered good practice for the site employer and external employer to formally, in writing, agree the suitability, reporting and dose control arrangements. As noted at chapter 3 care must be taken to ensure that all parties are aware of what dose record constitutes the legal dose record and the control dose record.

Prior to external employer's employees working within a specific sites controlled area it is considered good practice for the external employer and site employer to consult and agree mutual support and co-operation regarding the dosimetry aspects of the work including:-

- agreement and acceptance of written arrangements, it is considered good practice for this to apply for both classified and non-classified workers
- the likely risks and radiation exposure, including estimated doses where relevant
- suitability of external employers ADS supplied dosemeters for recording personal doses within the sites controlled areas, see section 4.2
- any relevant dose constraints, special dose limits or declaration of pregnancy or breast feeding see section 3.7.3
- designated and training requirements for the external employees
- the provision of information or instructions to comply with site local rules
- arrangements for radiation passbook and dose summary updates including arrangements to ensure accuracy and suitability of external employers dose record keeping arrangements particularly for non classified workers
- arrangements to ensure external employees remain in date for radiation related medical reviews and training
- the arrangements for dose monitoring and control, where relevant this may include internal dose assessment, special accident dosimetry, any special dose assessment arrangements
- support, co-operation and investigation arrangements in the event that work on site results in an external employee exceeding a legal dose limit or agreed dose constraint

Legally different arrangements are required for non-classified workers, however it is considered good practice to treat where practicable non classified workers in the same manner as classified persons. The site employer should ensure that the external employer is advised, in writing, of doses received by their non-classified external employees working on site.

IRR99 require that records of doses received by non site Employees working on an employer's site should be retained for a period of 2 years. License site conditions may require longer retention. It is however considered good practice for these records to be maintained indefinitely.

6.6. Establishing Personal Dosimetry Information

Good practice for site employer and an external employer is to establish and provide comprehensive dosimetry information before any employee enters a controlled area and in fact preferably before they arrive at a site to start work. This is not a formal IRR99 co-operation requirement but is considered good practice as it allows the site employer to make necessary arrangements to permit entry to controlled areas. Most sites achieve this by utilisation of a specific formal personal details form and radiation passbooks for classified persons. It is considered that at a minimum the following information should be obtained:

- Where the work will take place
- Personal details including title, surname, forenames, gender, date of birth, national insurance number, designation
- Employers details, dosimetry requirements, contact details for Dosimetry representative, RPA, RPS and any specific dose limits or controls required for the employer or employee
- Date access is required to Controlled Area
- Radiation dose to date, annual committed effective dose and any relevant extremity or internal dose sufficient to ensure that any additional dose accrued on site will not breach or challenge any dose limits or constraints
- For non classified worker or non EU person detail whether the employee has entered a Controlled Area in the calendar year. If so the dose details will be required

Before granting access to controlled areas the employee's relevant employer must be established. Where doubt exists it is good practice to treat the individual employee as a site employee in dosimetry terms.

The external employer is required to provide details of accumulated dose for external employees and trainees, and any estimates of doses where dose assessments are awaited prior to commencement of the work. It is considered good practice for the external employer to notify the site employer if any dose is subsequently believed to be, or is shown to be inaccurate at the earliest opportunity. In any case, the external employer should ensure that the results of outstanding dose assessments are provided as soon as practicable. Legally different arrangements are required for non-classified workers, however it is considered good practice to treat where practicable non-classified workers in the same manner as classified persons.

6.6.1. Non UK Nationals

Good practice is to treat all nationalities working on site at least as well as UK employees whilst also meeting any more stringent requirements of the employer or home nation. Certainly the site dose restriction policy should apply to all external employees regardless of employer or nationality.

EU Nationals: If the individual worker is employed within the EU as a category A worker (classified person) they should arrive with a completed radiation passbook issued by that countries competent authority and therefore be treated in the same manner as a UK classified person. See the attachment to this guide for typical example international radiation passbooks. If

they are not a classified person the site employer will need to establish a dose history in the same manner as for a UK non classified person.

Non EU countries have varying arrangements, some of which do not match those of the EU. Where uncertainty exists the individual worker should be treated as a UK citizen and arrangements made for Classification and ADS dosimetry or as for a UK non-classified worker. It may be prudent to advise the Office of Nuclear Regulation (ONR) Site Inspector at a licensed site whenever such arrangements are put into place

6.7. Site Employees Working Off-Site

On occasion site employee will be required to work offsite within the controlled areas of an external employer. Before travel commences arrangements should be agreed between the site employer and the employer of the site being visited. These arrangements will include agreement with regard to the dosimetry to be used for control and assessment, see paragraphs 6.5 and 6.6 for typical arrangements. If passive dosimetry is being supplied for the travelling workers, consideration should be given to the use of transit controls as advised by the ADS supplier and the RPA. Arrangements shall also be made for the results to be forwarded as soon as practicable to the relevant ADS record keeper and site employer as appropriate. Where these requirements can not be resolved the employer should consult the site RPA and ADS services as appropriate. Arrangements differ depending upon whether the individual is visiting a UK or European Union (EU) country compared to non EU countries, see following two paragraphs.

Off-site in UK and EU: For a site employee intending to work in Controlled Areas at other sites within the UK and European Union, Radiation Passbooks are required for classified persons and the details summarised at sections 6.5 and 6.6 apply. Legally different arrangements are required for non classified workers, however it is considered good practice to treat, where practicable, non classified workers in a similar manner to that employed for classified persons.

Non EU: Where a site employee intends to work in Controlled Areas in countries outside the European Union, the local dosimetry arrangements can not be considered as ADS assessments or measurements and therefore suitable dosimetry or dosimetry arrangements should be provided to the classified persons. It is considered good practice for non-classified workers to be treated in a similar manner or for suitable arrangements to be agreed between the employer and the relevant site operators.

6.8. Ceasing Radiation Work

Declassification of Classified Persons: Normally a classified person can only cease work as a classified person at the end of the calendar year: however this may also occur when:

- The Appointed doctor requires the person to be declassified, or
- The person changes employer, or
- The person ceases employment, or
- The person is no longer employed in a capacity which is likely to result in a significant exposure (e.g. effective dose at a rate exceeding 1mSv a year)

In all cases where a person is declassified, the employer is required to ensure the person and the ADS record keeper are advised of the declassification in writing. Any radiation passbooks raised for the

previously classified person should as appropriate either be returned to the ADS (yellow books only), or passed to the individual (blue books only) or retained by the employer.

Termination record: when a person who has previously been a classified person ceases employment, with the employer, the employer shall arrange for the ADS record keeper to forward a termination record to the person, with a copy provided to CIDI. It is considered good practice for similar arrangements to be made for non-classified persons.

Legally different arrangements are required for non-classified workers, however it is considered good practice to treat where practicable non classified workers in the same manner as classified persons as far as reasonable practicable, such as providing dose summaries on completion of radiation work.

6.9. Dosimetry Investigations

Requirements for a radiation employer to conduct a dosimetry related investigation include situations where:

- dosemeter issued to an individual has been lost, damaged or destroyed rendering its result unusable or unreliable
- there is reason to believe that an issued or used Dosemeter has been exposed to significant amounts of ionising radiations whilst not being worn and prior to formal measure/assessment
- it is believed that the dose record or dose history is significantly greater or significantly less that the dose received by the individual, see Annex 3
- it is suspected that a Significant Exposure has been received (e.g. from an intake of radioactivity, NDE exposure, site incident etc) but no dose measurement or assessment has been made
- where a significant loss of dosimetry data has occurred or is suspected

Note: A difference is considered significant when the Effective or Equivalent Dose differs from the recorded dose by more than 1 mSv (for recorded doses of less than 1 mSv) or by a factor of 2 (for recorded doses of greater than 1 mSv). However it is considered good practice to establish lesser differential values for investigation dependant upon the specific site working environments and related radiological risk assessments, see Annex 3.

It is considered good practice to have in place prepared formal reporting formats to assist in the dosimetry investigation process. The investigation should try to establish cause so as to prevent a reoccurrence. The site RPA should be consulted with regards to all aspects of the investigation including format, conduct and recommendations. Where an external employee is involved their employer and relevant representative such as their RPA, should be advised and consulted with regards to the investigation and provided with copies of the final report and relevant recommendations.

The investigation should attempt to estimate the dose received by the individual and/or, where appropriate, establish the cause of the loss or damage to the Dosemeter. The ADS (assessment and record keeper) should be consulted on dosimetry issues associated with the investigation. The individual who is the subject of the investigation, and where appropriate, the individual's appointed safety representative(s) and the relevant radiation protection supervisor should be notified that an investigation is taking place.

RPA or suitable dosimetry specialist advice should be sought to establish investigation requirements, where relevant, including:

- Estimated dose due to external or internal contamination, particularly when DAC or similar limits have been exceeded
- Dose significance
- Need to provide reassurance that no Significant Exposure has occurred and site arrangement remain adequate
- Need for a formal assessment of the dose received, including any internal exposure pathways

A typical investigation will include all or part of the following:

- Dates/times over which the investigation relates
- Location, site, the area of plant involved, equipment etc
- Relevant information about and provided by the individual(s) concerned including, employer, person full name, date of birth, National Insurance number etc
- Training, instruction, briefings and competence for the work undertaken
- Identification and details of personal dosimetry, personal radiation alarms including were worn, any readings and assessments available from the dosemeters including damaged or found dosemeters
- Work routine of individual and immediate work colleagues including dose histories and relevant dosimetry assessments
- Current and relevant historical dosimetry data related to the work area and tasks undertaken
- Measurements from any additional personal dosemeter, worn by the individual (or other individuals in the area) and the results of any additional dose assessments carried out (e.g. cytogenetic analysis)
- Any other relevant exposure information, in particular any known incidents involving unusual exposure
- Provision of and breaches of RPA recommendations, local rules, procedural controls, risk assessments etc
- Relevant radiation surveys, including those utilised to identify any deterioration in control measures or to attempt reconstruction of dose accrual
- Other possible explanations for the exposure under investigations, including medical exposures, inadvertent exposure of dosemeters to X-rays etc
- The reasons for believing that the recorded dose is incorrect (where appropriate)
- Estimates, broken down by Effective Dose or Equivalent Dose as provided, type of monitoring performed. Including where relevant body part/area, including any skin contamination
- The basis for any estimation of the dose received as detailed at chapters 4 & 5, which should be independently verified as relevant

The investigation should attempt to determine a reliable estimate of the dose received during the relevant period in order to determine whether or not a Significant Exposure was received by the individual or, where appropriate, was much greater or much less than the dose recorded.

The results of the investigation should be notified to the individual to whom it relates and a copy of the report made available on request. It is good practice for the employer to offer counselling and support, including Occupational Health professionals to individuals involved.

Where appropriate, the report should also be made available to the relevant safety representative.

6.10. Estimated Doses

On occasion there will be a requirement to estimate an individual's radiation dose. This estimate should be supported by a formal report, often a dosimetry investigation as noted in the preceding section. The estimate should be independently verified. The report of any dose investigation and any evidence used to produce an estimate of dose should be included or referenced in the individual's Dose Record or Dose History, by forwarding to the ADS record keeper, where relevant. Information must be timely and consistent to reassure the individual.

6.11. Notional Doses

Where there is inadequate information to estimate the dose received by a classified person the ADS (Records) shall be requested to enter a notional dose in the individual's Dose Record and identify the entry as such. Legally, different arrangements are required for non-classified workers, however it is considered good practice to treat where practicable non classified workers in the same manner as classified persons. It should be noted that for nuclear sites the arrangement, controls and methodologies should be such that the requirement for notional doses should be virtually irrelevant. However occasionally these may be seen to be utilised by external employers.

6.12. Special Entry Dose

Where it is believed that the dose already recorded in classified persons Dose Record or History is much greater or much less than that received, any change is termed a special entry, see note within section 6.9.

The employer may only request the ADS Record Keeper (in a format agreed with the ADS) to make a special entry in an individual's Dose Record in the following circumstances:

- where an investigation has been conducted and a satisfactory estimate of the dose received has been made and:
- the original entry in the Dose Record was made less than twelve months previously (five years for an employee subject to a five year dose limit)

Where an employer has reasonable cause to believe that this has happened an investigation as noted in the preceding section should be conducted and the dose estimated, recorded and forwarded to the ADS record keeper as a special entry. HSE approval is required for special entries over legal Dose Limits. The individual to whom the Dose Record relates shall be notified of these changes, they will have a right of appeal. It is also considered good practice to involve the individual in all stages of the process.

Where the above circumstances do not apply, but where there is a significant difference in recorded dose is established it is considered good practice for the details to be recorded and for the record to be attached to or included within the individual's records.

Legally different arrangements are required for non-classified workers, however it is considered good practice to treat where practicable non-classified workers in the same manner as classified persons.

6.13. Dose Limitation For Over Exposed Employees

IRR99 provide at regulation 26 a facility that allow where an individual has exceeded a legal dose limit they may be permitted to continue work with ionising radiations provided

- that an investigation and notification to the HSE has been completed, see section 6.9
- employee has been subject medical surveillance by the appointed doctor for over exposed workers in accordance with IRR99 Reg 24
- work is in accordance with requirements of appointed doctor
- work is subject to a stated proportional dose limit of the relevant annual limit for the year that the overexposure was received, five year dose limit if relevant and any other limit or constraint as appropriate

6.14. Radiation Accidents and REPPIR

As part of site emergency arrangements the site employer should have in place dosimetry provision for personnel likely to be involved in or effected by a site radiation accident, including site staff and others such as emergency services personnel etc, who would expect to respond to the event. These arrangements will also include agreement as to the dose limits that shall apply in emergency circumstances. Also in accordance with the relevant risk assessment the routine dosimetry provision should be suitable to record any reasonably foreseeable accident dose. These arrangements and the related dosimetry appropriateness assessment etc. should be documented.

At section 2.2 the dosimetry related legal requirements for radiation accidents and REPPIR are detailed. There is a clear distinction made between emergency exposure under REPPIR and radiation accident exposure detailed within IRR99 Regulation 23. Where an assessment shows workers could receive doses in excess of 500 mGy, the employer has to consider whether 'Special Accident' dosimetry is required. The site employer will need to separately appoint one or more ADS with approval for 'Special Accident' and/or REPPIR dosimetry. These ADS approvals may require the site employer to provide separate arrangements to measure, assess and record 'Special Accident', REPPIR and operational dosimetry. To avoid confusion, particularly during an accident situation, it is considered good practice, where practicable to avoid this distinction at the point of issue.

6.14.1. IRR99 Dosimetry for Accidents:

Where an assessment shows that a radiation accident is reasonably foreseeable the site employers contingency plans will include issue of appropriate dosemeters supplied by an ADS approved for issue of appropriate dosimetry capable of recording the dose predicted within a radiation accident or other foreseeable overexposure, which may include special accident dosimetry approval. Where any accident or other occurrence takes place which is likely to have resulted in an individual receiving an Effective Dose exceeding 6 mSv or an Equivalent Dose greater than three-tenths of any relevant dose limit, the site employer shall arrange, as soon as possible, for a dose assessment to be made by the ADS (Assessment), preferably meeting the timescales noted for special accident dosimetry, see next paragraph. The ADS should be advised of the details as soon as it is known that there is a requirement.

6.14.2. Special Accident Dosimetry:

Where an assessment shows workers could receive doses in excess of 500 mGy, IRR99 regulation 23 requires the employer to appoint an ADS that has been approved to measure high doses (from 0.25 Gy to 10 Gy) reliably and accurately. The ADS must be able to:

- Rapidly (within 8 hours) identify individuals likely to have received doses of >1 Gy so as to identify individuals who may require urgent medical treatment
- Provide initial assessments of doses >0.5 Gy with <50% uncertainty within 48 hours
- Provide refined assessments of doses >0.25 Gy with <30% uncertainty within 7 days

Where two dosemeters are assessed by different ADSs, one ADS will need to be appointed to the coordination role, and will be responsible for the combination of the dose assessments and onward reporting. Arrangements will need to be in place to transport dosemeters to the ADS promptly. Whilst the 8-hour timescale only starts upon receipt of the dosemeters at the ADS, good practice would be that the ADS would be able to complete the highest priority assessments within 8 hours of the incident. See Annex 6 for a description of criticality dosimetry.

6.14.3. REPPIR:

The Radiation (Emergency Preparedness and Public Information) Regulations 2001 are concerned with doses received by intervention personnel once an "Off-site Nuclear Emergency" has been declared. Intervention personnel must only be allowed to receive emergency exposures in excess of the limits detailed within the IRR99 for the purposes of saving life, helping endangered people, preventing large numbers of people from being exposed to ionising radiation, or saving valuable installations or goods. REPPIR regulation 14 is not concerned with doses received by employees who may be exposed to ionising radiation as the result of the radiation accident that leads to a radiation emergency. Such doses are subject to the requirement of IRR99 regulation 23. In addition the site employer has to make arrangements for the assessment and recording of intervention doses with an ADS which has specific REPPIR approval. The site employer when appointing a REPPIR ADS will need to supply details of the anticipated emergency dose levels notified to the HSE.

6.14.4. Other Accident Dosimetry Methods

Where it is identified within the radiological risk assessment that an individual may receive whole-body doses in excess of 100 mSv in a short period of time (day or less) contingency dosimetry assessment arrangements should be identified, documented and put in place. As part of these arrangements there may be a requirement to undertake biological effect dosimetry, this is a highly specialised field and specialist advice should be sought. One option is Chromosomal Aberration Dosimetry. This involves providing a blood sample for dispatch to the analysing laboratory and has a detection threshold of around 100 mGy of X or gamma rays, see Annex 7.

7. COLLECTIVE DOSE MANAGEMENT, REPORTING AND PERFORMANCE INDICATORS

7.1. Performance Indicators

As part of demonstration of ALARP, Licensees use a number of dose quantities for optimising exposure. As part of the ALARP framework, sites use terms such as Company Dose Restriction Level, Radiation Safety Objectives, dose budgets or dose restraint objectives to support ALARP demonstration or the Company Dose restriction policy see Table 3.

Table 3: Dose Measurements

Measure	Driver/Origin
Individual Dose	The IRRs require radiation employers to monitor individual dose on annual basis (January to December)
Collective Dose	Used in ALARP studies for planning and optimisation
Average Dose	Licence condition 18 requires licensees to monitor the average dose equivalent and report if the average exceeds a value specified by the Regulator.

Some sites also agree performance indicators with stakeholder's e.g. NDA, local liaison committees and customers as part of targets to demonstrate safety as Key Performance Indicators. The ONR have discussed Site Performance Indicators which include dose with licensees and other concepts as 'leading' and 'lagging' indicators of performance. The site policy should identify the difference between the site performance indicator, company dose limit and subsidiary facility or project based targets and should use Calendar year for reporting.

The site employer's dosimetry arrangements can easily supply statistics for comparison. However comparison may not be on a like for like basis, and therefore should be used with caveats. For example decommissioning activities will have different dose profiles to operational reactor profiles which will require stakeholder dialogue.

The population averaged over (and any of the above statistics) should be one or more of the following categories

- All Personnel Issued With Dosimetry
- All Workers with reports above detectable thresholds (thresholds declared)
- All classified persons
- All workers with annual dose >1mSv.
- Key Activity Groups

Note care needs to be taken with regards to itinerant workers

Table 4: Some Dose Measurement Comparison Issues

Indicator	Comparison issue	Recommendation
Individual Dose	Background calculation, thresholds, bioassay regime, site activity.	Use significant dose e.g. > 5 mSv on a Calendar basis
Collective Dose	Related to site activity, can be derived from safety cases, regulation 7 as a 'leading' indicator to predict performance	Use dosimetry derived indicators as opposed to calculation or use correction factor from project dose to dosimetry based indicator
Average Dose	Depends on definition	See below

Notes

Individual Dose: As discussed in previous chapters, there are a number of concepts to bear in mind when comparing doses (e.g. background calculation) however by choosing a criterion for comparison for significant dose e.g. 5 mSv these issues are minimized.

Collective dose: Collective dose can be derived from safety cases, ALARP studies and prior risk assessments. However these have a number of assumptions and therefore, use as a performance indicator should be treated with caution.

Average Dose: There are a number of average doses which may be defined as there are a number of possible Collective doses over a population, the usual being the sum of effective dose and committed effective dose (or better known as simply the sum of external + internal whole body dose).

For Average doses to be relevant care has to be taken to ensure the cohort being averaged is comparable and the sample population defined. For instance there is no point in averaging doses over a group containing both decommissioning staff and lab workers; the average result would be unlikely to provide useful information. Also including low or zero dose individuals within a cohort with predominately high personal doses will lead to misrepresentation of the actual operational circumstances.

7.2. Collective Dose

Collective dose is utilised as a radiation protection tool to help quantify potential harm from radiation exposure to certain population groups. ICRP 103 states the collective effective dose, S is calculated as the sum of all individual effective doses over the time period or during the operation being considered. The term used to quantify collective effective dose is the 'man Sievert' or more commonly man mSv.

To ensure that collective dose is used in the appropriate manner, those reporting such information should consider the following:

- Do not set regulatory limits on collective dose
- Apply with caution to an uncharacterised population
- Do not apply to a population whose size is uncertain by an order of magnitude or more
- Limit the application of collective dose to stochastic effects
- Project to future populations and situations with care
- When the collective dose is less than the reciprocal of the risk factor, choose zero as the most likely number of excess cancer deaths

- Whether all doses should be used for calculating collective and average individual dose

Limitations of Collective Dose: ICRP 130 highlights limitations with the application of collective dose. The salient point to remember, is that collective dose is an indicator of societal risk and not individual risk: collective dose should be used only if the exposed population and the radiation doses to its members are very well characterised.

Calculation: The collective dose (S) is the sum of the individual effective dose (En) of a group of people over a known period of time e.g. yearly, or for major projects or tasks.

Collective Dose

$$(S) = \sum En$$

Average Collective Dose

$$(S) = \underline{\sum En/N}$$ Where N = the Population number for the group under consideration

7.3. Arrangements for Collective Dose Management

Individual nuclear establishments will have their own preferred arrangements for managing collective dose.

The following management arrangements are examples used by nuclear sites, but are not exclusive to one particular site:

- Pre-work ALARP reviews for work likely to result in collective dose above a certain level
- Dose predictions prepared at the planning stage for particular tasks/projects and monitoring against such predicted doses
- Use of radiation safety objectives for monitoring an agreed collective dose against a yearly project plan
- Use of APD's to monitor individual, collective and average individual doses on a daily or weekly basis and to track particular groups of workers
- Daily or weekly monitoring by the use of task codes and agreed daily levels, particularly if contractor collaboration is required
- Review of collective and average individual dose on a monthly basis

7.4. Collective Dose Reporting

It is a requirement for Licensees of Nuclear Licensed Sites, under Licence condition 18 (radiological protection), that adequate arrangements are implemented to assess the average effective dose. It also requires the Licensee to notify the HSE if the dose exceeds a specified level. This is complementary to the Ionising Radiations Regulations 1999, regulation 25. This can therefore only be obtained by the use of the collective dose.

Furthermore, Safety Assessment Principle (SAP 92 (2006), 25(P3)) states that collective effective dose to operators and the general public as a result of operations of Nuclear Installations should be kept ALARP. Collective dose reporting is therefore required for many external and internal organisations, to

ensure that Licensees protect workers and the public from ionising radiations from their activities on their sites.

When reporting collective dose it is important that the definition of the group of individuals is included. For example; all classified radiation workers, or all non-classified workers, all individuals receiving a dose below a set criteria, or individuals within a defined work area.

Consideration should be given to the inclusion or not of individuals receiving zero dose dependant on the future use of the data. For example if the collective dose is from a group of individuals undertaking a particular task then all dose data should be considered however if the data is for calculation of average dose in a business or area for comparisons then it may not be appropriate to include zero doses because of the potential dilution effect.

7.4.1. External Organisations

All businesses will have slightly different stakeholders with reporting requirements. Examples may include:

- ONR
- Local residents via a liaison committee
- Business Partners
- Other radiation employers on same site
- Outside Workers

7.4.2. Internal Organisations

Again businesses will have differing requirements for reporting. Examples may include:

- Safety Committees
- Improvement Committees
- Area management
- Directors

7.4.3. Presenting the collective dose data

Collective dose can be reported to external and internal organisations in various ways. The information provided to the groups can consider total dose reporting (man mSv), the number of individuals used for collective dose and the average individual dose from such data.

As previously mentioned, consideration should be given to the inclusion or not of individuals receiving zero dose. Organisations must ascertain whether collective dose reports with averages, should include the average of all workers or solely specific groups such as only classified persons, in any statistical analysis. This is important when considering average dose and how this information is to be used.

Organisations will have their preferred method of presenting their statistical data from collective dose, either in a tabulated form, as a graph or as a histogram or a combination of methods. Figure 6 gives an illustration of how collective dose data can be presented in a graphical format to the various organisations requiring it.

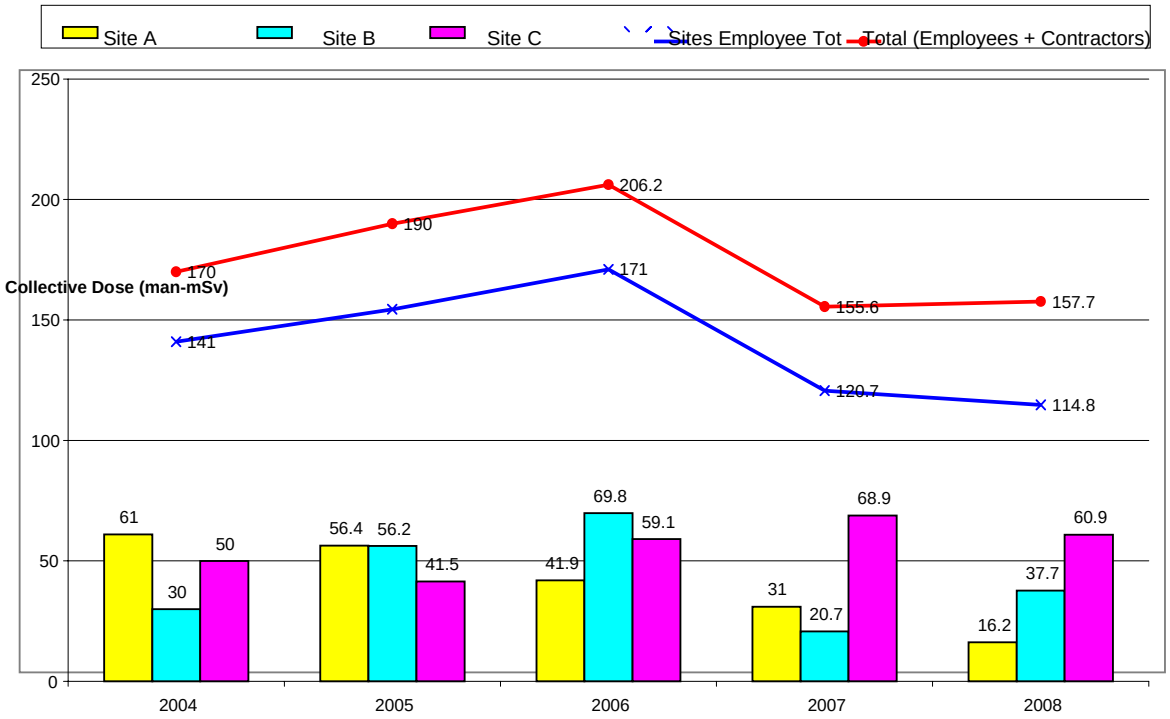

Figure 6: Collective Employee Dose (man-mSv)

Table 5: Typical Site Radiation Worker Annual Dose Breakdown

	2006	2007	2008	2009	2010
Classified Persons					
Number of Persons Drawing Dosimetry	545	527	512	453	442
Persons with Annual Dose > .000mSv	539	521	497	445	432
Highest Individual Dose mSv	2.56	3.00	2.9	3.3	3.4
Average Individual Dose mSv	0.63	0.68	0.54	0.81	0.64
Total Dose man mSv	348	360	274	367	282
Non-classified persons					
Number of Persons Drawing Dosimetry	1197	1115	1025	1056	939
Persons with Annual Dose > .000mSv	940	837	802	796	675
Highest Individual Dose mSv	2.59	2.18	2.1	3.1	2.7
Average Individual Dose mSv	0.13	0.20	0.15	0.20	0.12
Total Dose man mSv	156	170	149	214	113
Totals					
Number of Persons	**1742**	**1642**	**1537**	**1509**	**1381**
Total Dose man mSv	**504**	**530**	**423**	**581**	**395**
Average Individual Dose mSv	**0.29**	**0.32**	**0.28**	**0.39**	**0.29**

It is usual for dose data to be compared with previous year's doses and a suggested period by the ONR for comparison of such data is 5 years. The following tables are examples of possible tabular presentation of dose information.

Table 6: Typical External Employee Radiation Worker Annual Dose Breakdown

		2006	2007	2008	2009	2010
Classified	No Workers	149	154	147	167	127
	Dose man mSv	72	51	79	65	59
Non-Classified	No Workers	520	553	600	636	536
	Dose man mSv	59	52	53	41	49
Totals	No Workers	669	707	747	803	663
	Highest Individual Dose mSv	3.90	3.3	3.5	2.48	2.5
	Average Dose mSv	0.20	0.15	0.18	0.13	0.16
	Dose man mSv	**131**	**103**	**132**	**106**	**108**

Table 7: Typical Annual Dose Range Distribution

	Number of Staff in Dose Bands mSv				
	<0.050	**>=0.050 <=1.000**	**>1.000 <=2.000**	**>2.000 <=3.000**	**> 3.000**
Site Employees	862	733	102	45	0
Non Site Employee	499	272	25	7	0

Table 8: Typical Site Employer/Cost Centre Breakdown

Cost Centre/Other Employer Collective Doses Greater Than 2mSv	**No Individuals**	**Collective man mSv**	**Average Individual mSv**	**Highest Individual mSv**
Production Trades and Specialities	**333**	**216**	**0.65**	**3.4**
Reactor Fitter	*18*	*46*	*2.56*	*3.4*
RC Cleaner	*28*	*34*	*1.20*	*1.6*
Fabricators	*29*	*35*	*1.20*	*2.4*
Reactor Section NI	*35*	*23*	*0.66*	*2.3*
RP Laggers	*33*	*22*	*0.67*	*1.3*
RP Electrical	*17*	*11*	*0.65*	*1.4*
RP WSMI Welder	*3*	*5*	*1.67*	*2.0*
RP Welder	*9*	*10*	*1.11*	*1.8*
RP M Pipefitter	*11*	*5*	*0.45*	*0.8*
RP Sail maker	*5*	*3*	*0.60*	*1.0*
RP Sub Nuclear Other	*12*	*4*	*0.33*	*1.0*
Left Reactor Production/Less than 2mSv	*133*	*18*	*0.14*	*1.4*
Support Company A	**115**	**46**	**0.40**	**2.3**
Health Physics	**115**	**44**	**0.38**	**1.3**
Refuel Teams	**100**	**37**	**0.37**	**1.5**
Test Centre	**95**	**22**	**0.23**	**2.8**
Engineering Company B	**6**	**9**	**1.52**	**2.1**
Engineering Company C	**6**	**8**	**1.30**	**2.0**
Radiochemistry Labs	**45**	**8**	**0.18**	**2.2**
Welding and Design	**58**	**9**	**0.16**	**0.6**
Support Trades	**20**	**6**	**0.30**	**1.3**
Insulators	**30**	**5**	**0.17**	**1.2**
NDT	**4**	**4**	**1.00**	**1.1**

Table 9: Typical Project and Task Breakdown

Project No and Title	Start	End	Dose Man mSv	
Tasks with doses >= 4 man mSv			Estimate	Actual
Maintenance Project A	**Oct 08**	**Ongoing**	**606**	**531**
Steam Generators				*76*
Primary Circuit				*74*
Emergency Cooling				*73*
Refuel				*49*
Pressuriser				*33*
Support Cooling				*26*
Cleaning				*20*
Health Physics Duties & Tasks				*19*
Tertiary				*18*
H & S Fire and Rounds				*16*
Insulation				*12*
Instrumentation and Control				*10*
RPV				*9*
Coolant Treatment System				*8*
NDE				*8*
Neutron Detectors				*7*
Shielding				*6*
Coolant Make-up				*6*
Main Coolant Pumps				*4*
Remainder				*57*
Upkeep Project B	**Aug 09**	**Aug 10**	**194**	**200**
Primary				*57*
Support Cooling				*24*
Surge Line				*17*
Cleaning				*15*
Lagging				*14*
Pressuriser				*11*
Steam Generators				*9*
H & S Fire and Rounds				*9*
Relief System				*6*
Health Physics Duties & Tasks				*4*
Refuel				*4*
Coolant Make Up				*3*
Remainder				*20*

8. GOOD PRACTICE SUMMARY

The purpose of this chapter is to provide site employers, radiation protection staff and dosimetry services with a summary of the main principles that should be considered during decision-making processes regarding a system of dose management.

A review of dosimetry requirements may be undertaken for either the setting up of a new system or as a review of an existing system to assess the continuing suitability of that system.

The table below can be used as a check-list by site employers setting up or reviewing a dose management system.

The starting point of any review should be a Prior Risk Assessment under the Ionising Radiations Regulations 1999, Regulation 7 (Section 2.1 and Annex 2). This provides a framework for assessment of the radiological hazards present, those persons affected, the constraints of the environment and any controls/mitigations that are present.

This information will drive the dosimetry requirements, such as type of dosimetry required, dose sensitivity, cost, bioassay requirements and suitability for particular radiations & energies.

Relevant sections of this Good Practice Guide are referenced where required. Two examples are given in section 8.2 as an aid to the use of this summary chapter.

8.1. Dose management considerations

A summary of what is considered as good practice when undertaking a review of dose management arrangements is shown at Table 10, Table 11 and Table 12, below. Table 10 covers those considerations that should be covered as part of the IRR99(7) Prior Risk Assessment process. Table 11 goes onto cover those considerations driven by the conclusions of the Prior Risk Assessment. Table 12 covers those considerations that are based on site employer and operational requirements.

Table 10: Good Practice - The prior risk assessment process

Consideration	Description	GPG section Reference
Nature of the radiological hazard	**Exposure pathways** The exposure pathways will determine the overall dosimetry requirements, i.e. whether external dosimetry for radiation fields, internal bioassay for contamination environments, or a combination of both is required. **Radiation/ radionuclide type** The radiation type will determine the type of dose that will need to be measured and assessed, i.e. whole body gamma, extremities, internal exposure. For internal exposures, the radionuclide will determine the bio-kinetics in the body and	**3.1** **4.1** **5.1**

Table 10: Good Practice - The prior risk assessment process		
Consideration	**Description**	**GPG section Reference**
	hence the choice of suitable bioassay. **Physical and chemical form** The physical form of any radioactive material (solid, particulate, gaseous, liquid) including specifics such as particulate size will influence the exposure pathways. The chemical form will also heavily influence the exposure pathway, with soluble material being more readily absorbed into the body and hence increasing the exposure. **Radiation energies** The radiation energies (especially for external exposure) will affect the choice of dosimetry based on the detection efficiency of the dosimetry at that energy and the dosimetry packaging, i.e. for low-energy x-rays, a thick plastic dosemeter case may not be suitable. **Radiation field geometry** Dependant on the radiation field geometry, several dosimetry components may be required, for instance if a non-uniform field is present, it may be suitable to use more than one dosemeter element to help calculate directional components of dose received. **Radiation dose-rates** The level of radiation by which a person may be exposed will have an effect on suitable dosimetry, i.e. for flash-x-ray work, electronic dosimetry may not respond fast enough to record the potentially high doses, and for low-level chronic radiation fields, dose sensitivity and fading effects of dosemeters will be important. The exposure rate will also help determine the classification of workers.	
Persons affected	**Directly exposed staff** These are persons directly carrying out the work involving ionising radiation. These will be the highest-exposed group of people and hence dose management arrangements will be based on these people's exposures.	**2.2** **3.2** **3.7.6** **3.7.3** **6.4**

Table 10: Good Practice - The prior risk assessment process		
Consideration	**Description**	**GPG section Reference**
	Pregnant and Breast Feeding Mothers Pregnant or breast-feeding radiation workers that have declared their current state to the site employer must have the potential dose to the foetus assessed as part of their dosimetry regime. Additional controls to reduce dose or additional dosimetry may also be introduced to their working arrangements. Particular care and additional controls must be considered where radionuclides that preferentially affect the placenta/foetus are present in the workplace. Similar care must also be considered where unsealed sources are present and the worker is still breast-feeding. Companies may have corporate policy preventing/limiting pregnant/breast-feeding radiation workers (that have declared themselves) access to designated areas. This decision will either be a blanket policy or based on individual-case risk assessment **Other facility staff** These are persons that are working in a designated area but not directly involved in processes involving radioactive material or sources. Dosimetry arrangements for this group may have to take into account exposure to several radiation fields within the area, rather than a single radiation field as may be the case with the directly exposed staff. **Staff external to designated area/facility** These are persons that may occasionally enter a designated area or purely by virtue of working on a site be exposed to a higher-than-normal radiation background. It is unlikely that these people will warrant being classified persons. **Public** Members of the public are persons that do not work for a radiation employer and will not be undertaking work with ionising radiations, and hence are subject to the public dose limits under IRR99.	**6.5** **6.6** **6.7** **6.14**

Table 10: Good Practice - The prior risk assessment process		
Consideration	**Description**	**GPG section Reference**
	Itinerant workers For radiation employers with more than one site, any dose management system must be able to track doses received on individual sites in a central location, such that there is no risk of overexposure through working at several sites throughout the year. **Outside workers** Outside workers undertaking work on an operators site may have dosimetry arrangements in place with an external ADS. Arrangements will need to be in place to take these doses into account, especially for long-term outside workers on the site if their doses are to be included as part of the sites dose performance, this could be through liaison with the external ADS or through issue of an additional dosemeter by the site ADS. **Emergency responders** These may be either site responders such as Civil Nuclear Police, MoD Police, Site Fire & Rescue or from external agencies such as HO Police, UK Ambulance Service or UK Fire & Rescue. Provision must be made for supplying dosimetry at short-notice to external responders in the event of a site radiation incident that they may attend. **Other considerations** Trainees of less than 18 years of age, and women "of reproductive capacity" are subject to different dose limits under IRR99 Schedule 4, which may introduce a requirement for separate dose management arrangements for these persons.	
Work environment	**Atmosphere** Temperature and humidity may have an effect on the performance of particular dosimetry. Particular consideration should be given to work carried out involving tritium, as atmospheric conditions may affect the exposure pathway (HT and HTO) **Confined spaces** If work is carried out in a confined space, such as for	**3.1** **Annex 5** **4.3** **6.1**

Table 10: Good Practice - The prior risk assessment process		
Consideration	**Description**	**GPG section Reference**
	maintenance tasks or some decommissioning operations, consideration will need to be given on the size and durability of personal dosemeters. **Handling of radioactive materials** If the work involves the handling of radioactive materials or sources, especially those involving beta or low-energy X/gamma radiations, specific consideration to the measurement and assessment of extremity doses will need to be given. **Potential for wounds during work** In areas involving contamination, consideration should be given to dose assessment from wounding incidents (i.e. if carrying out cutting operations on contaminated items). This may necessitate the sourcing of specific monitoring equipment in case an incident occurs, as part of both the site's dose management and contingency planning systems. **Duration, scale and frequency of work** For frequent work involving large numbers of radiation workers, a dose management system that involves low-cost dosimetry, and quick turn-around of dose assessments may be required to allow managers to review the doses to their staff and prevent back-logs of dosimetry within the ADS. Large scale operations may require the appointment of a suitable ADS that can handle a sufficiently-high through-put. It should be noted that internal dosimetry generally will not have a quick turn-around time due to the nature of the chemical processes and analysis methods required to be carried out by the ADS. **Other hazards** Explosive environments may require that any dosimetry systems in use are intrinsically safe, hence passive dosimetry may be the most appropriate method, if real-time monitoring is not a requirement. Dosimetry for fire crews at nuclear sites may need to be insensitive to high temperatures, hence thermo-luminescent devices may not be appropriate means of measuring dose for these environments	

Table 10: Good Practice - The prior risk assessment process		
Consideration	**Description**	**GPG section Reference**
Existing radiological controls	**Containments/Shielding materials** Consideration should be given to any shielding, containments or mitigating material which may affect the radiation spectrum emitted from a material/source. This is particularly important for beta/bremsstrahlung, gamma and neutron sources. Any degraded spectrum will need to be taken into account in order to choose dosimetry with the appropriate energy sensitivity. **Existing area/facility design or work practices** Design features such as ventilation systems found within a facility may reduce exposures to airborne radionuclides and hence influence the dosimetry requirements for staff in those areas. Any existing practices such as air monitoring, task-based monitoring or specific working practices may also provide existing controls that influence dosimetry decisions, whether it be the type or frequency of the dosimetry regime.	**3.1** **4.1** **4.2** **4.3**
Foreseeable accident scenarios	**Accident dosimetry** Dosimetry used must be suitable for both normal operational doses and foreseeable accident scenario doses. This may be covered by a single dosimetry technique, or specific additional dosimetry techniques provided for accident scenarios, i.e. passive criticality dosemeter lockets for work involving fissile material. Whatever the technique employed, it must be able to measure the radiation energies, types and levels identified within the appropriate risk assessment. **REPPIR** Those sites that have identified radiation accident scenarios that may result in a member of the public receiving 5 mSv or more in a calendar year due to the accident are required to have an emergency plan set up under the REPPIR regulations. From a dose management perspective, this will require procedures for the measurement, analysis and reporting of any potential intervention doses received by emergency responders. This may require specific dosimetry arrangements to be in place aside from the normal operational arrangements. REPPIR dose assessment MUST be carried out by a REPPIR-approved ADS.	**2.2** **4.3.8** **5.3.2** **6.14**

Table 11: Good Practice – Considerations from Prior Risk Assessment		
Consideration	**Description**	**GPG section Reference**
Minimum detectable dose required	Consideration will need to be given as to the dose resolution required by the site operator. For low-dose environments, a dosimetry system with high resolution will be required in order to accurately record an annual dose that may be less than 1 mSv, for example.	**3.5 to 3.7** **4.1 to 4.4** **5.2** **5.3**
Type of dosimetry	Based on the outcomes of the Prior Risk Assessment, a set of criteria can be established as to the requirements of the dosimetry system for an undertaking. These criteria can then be assessed against the various systems on the market, or for sites that use an external ADS, these criteria can be used to assess the appropriateness of their ADS. The general dosimetry types that would be required are: • External: Passive (i.e. TLD badge) • External: Active (i.e. Active personal dosemeter) • Internal: Environmental (i.e. workspace air monitoring) • Internal: In-vitro (i.e. urine, faecal) • Internal: In-vivo (i.e. whole-body monitor)	**3.5 to 3.7** **4.1 to 4.3** **5.2** **5.3**
Selection of ADS	Based on the dosimetry requirements (i.e. type of dosimetry, detection limits, turn-around times, numbers required) specific to the workplace of interest, the ADS to be used must be able to meet these requirements. It must be a **suitable** ADS.	**3.7.4** **6.2**
Classification of workers	The nature of the work environment will identify those persons that are to be classified under IRR99 (20) and hence those persons that will require dosimetry. The numbers of persons requiring dosimetry may have direct impact as to the choice of system, where cost is concerned.	**6.4**
Outside workers	Depending on the terms of contract, an outside worker may either have their own ADS and dosimetry or request the use of the site operators ADS. If the outside worker uses their own ADS and dosimetry, it is considered good practice to supply them with approved site dosimetry for the duration of their work on site. This allows assigning of dose received specifically at the operator's site and subsequent completion of the outside workers passbook (see also "persons affected – outside workers", above).	**3.7.6** **6.5** **6.6** **6.7**
Non-classified workers	Persons on a site may be identified as not meeting the requirements for classification as a classified person, yet are	**3.7**

Table 11: Good Practice – Considerations from Prior Risk Assessment		
Consideration	**Description**	**GPG section Reference**
	still exposed to ionising radiation during their work. It is considered good practice to provide these persons with dosimetry and record their doses. This has advantages, i.e. providing ALARP justifications for undertakings, allows data to be collected for epidemiological studies into the effects of chronic low radiation doses, and supports future claims through the radiation worker compensation scheme.	**6.4** **6.6**

Table 12: Good Practice - Considerations from Site employer/Operational Requirements		
Consideration	**Description**	**GPG section Reference**
Data / records storage and infrastructure requirements	The type of data capture and recording system will depend on the size and throughput of the site, the cost of required infrastructure and the methods and frequency of reporting that may be required. For large sites, it may be justified to set up an electronic, automated database system, allowing interrogation of dose data from many persons and groups and to easily collate information for ALARP justifications and trending. For smaller sites or infrequent radiation work, a paper-based system may be all that is required, in order to record and track doses for a small number of individuals. Each system has pros and cons, relating to cost of implementation, IT infrastructure, site dosimetry office staff numbers, training requirements on staff, maintenance costs, reliability, and retrieval and analysis of records. The cost-benefit criteria will be specific to the company undertaking the radiation work.	**3.6** **6** **6.1**
Reporting method and frequency	**Reporting method** This is related to the above data storage methods. An electronic system has the advantage that it can be	**3.5.5** **3.6**

Table 12: Good Practice - Considerations from Site employer/Operational Requirements		
Consideration	**Description**	**GPG section Reference**
	automatically generated and sent to a large number of people (i.e. supervisors, project managers, RPA's) easily. It also allows analysis and trending of data to be included in the report, as well as graphs if required. Electronic reports are especially useful for large sites, where paper-based systems would quickly accumulate and require large records storage areas. Paper-based reports have such advantages as reliability, less dependence on expensive infrastructure, and provide a permanent record that can be kept safely for many years. The disadvantage of paper-based dose reports is that it requires further work by the RPA, supervisor etc if analysis and trending of doses is needed. **Reporting frequency** For sites that involve frequent (i.e. daily) work in areas of high levels of radiation or contamination, RPA's and supervisors may require frequent, perhaps even daily reporting of doses in order to ensure that staff are not being overexposed and that doses are kept ALARP. For these types of situations, particularly for large sites, passive dosemeters and bioassay analysis may not be appropriate due to the time required to perform the dose assessment. These types of work activities may benefit from active dosemeter systems that automatically upload dose data to a central database at the end of a work period and automatically generates dose reports at the frequency required. This is assuming that the active dosemeter is appropriate to the radiation fields and exposure pathways encountered for that work activity. For example, If the radiological hazard is actinide contamination, an active dosimetry system may not be seen to be beneficial, when the dominant hazard may be due to internal exposures. For most work activities, this level of time-resolution will not be required and a passive dosimetry/bioassay system may be used. Supplementary data from characterisation of source-terms, and workspace monitoring and sampling can be used to support the legal dosimetry programme to estimate likely operational doses and ensure that doses	**5.2** **6.1** **6.8** **6.9** **6.10** **6.11**

Table 12: Good Practice - Considerations from Site employer/Operational Requirements		
Consideration	**Description**	**GPG section Reference**
	remain ALARP. **Investigations** The site employer must have arrangements in place to undertake a dose investigation if an actual or suspected overexposure of an employee has occurred. A dose investigation will also be required where dosimetry is missing/lost/damaged or where a special entry is required on a dose record. **Missed dosimetry and responsibilities of staff and line managers** It is considered good practice to have in place a means of flagging, investigating and minimising missed and unreturned dosimetry. This is seen to be an issue particularly for large sites with many radiation workers. It should be ensured that line managers and staff are aware of their responsibilities with regards to dosimetry and the importance of returning dosimetry, completing bioassay samples and informing the ADS should the status of a worker change (different building, nuclides or no longer requires dosimetry etc). **Radiation workers ceasing radiation work or employment** On ceasing radiation work with an employer, a termination record will need to be issued by the ADS to the employer and individual prior to the recommencement of radiation work Recommencement may be with the same or a new employer.	
Company dose objectives and limits	Corporate or local dose constraints/ targets may influence dose management arrangements such as dose investigation levels, and the frequency/type of dose reports required in order to demonstrate progress with respect to such corporate constraints/ targets.	**3.2** **6.3** **7**

8.2. Dose management examples

The two fictional examples at Table 13 and Table 14 below are not intended to be exhaustive analyses but rather a means to gain further insight into what may be considered when setting up or reviewing a dose management system.

Table 13: Example A: Large-scale plutonium decommissioning programme	
Consideration	**Description**
Nature of the radiological hazard	• Plutonium 239, low energy x-rays + Am241 in growth (60keV) • Bulk material, oxides, particulate • Surface contamination up to 5000 Bq/cm^2 (alpha) • Airborne concentrations up to 10 kBq/m^3 (alpha) • Dose rates up to 100 µSv/h
Persons affected by the undertaking	• Decommissioning operatives (contractors) x 40 • Facility operations staff (contractors) x 40 • Project management team x 20
Work environment	• Mixture of open lab areas and confined plant spaces
Existing radiological controls	• Ventilation system and modular containments around active high-level decommissioning areas, legacy glove-boxes, RPE (positive-pressure breathing air suits)
Foreseeable accident scenarios	• Breach of containment systems, failure of ventilation, breach of legacy glove boxes, contaminated wounds, failure of RPE, criticality
Minimum detectable dose required	• 10 µSv whole body dose
Type of dosimetry	• Entrance bioassay (baseline) sample • Thermo-luminescent dosimetry (legal external exposure dosemeter) • Electronic dosemeter (task-based dosimetry to ensure doses are ALARP in high dose-rate areas) • Passive criticality locket (accident dosimetry) • Personal air sampler (PAS) (non-legal task-based reassurance dosimetry) • Annual bioassay (Plutonium/Americium in Urine and Faeces) • HPGe wound monitor system available onsite due to potential for contaminated wounds
Classification of workers	• Decommissioning operatives = classified persons • Facility operations staff (contractors) = Classified persons • Project management team = non-classified workers (See “persons not normally exposed”, below)
Visitors and outside workers	• Visitors will be supplied with dosimetry – TLD and electronic dosemeter. Visitor form kept with records office for future reference • Contractors arranged to use site ADS, passbooks updated with annual doses.

Table 13: Example A: Large-scale plutonium decommissioning programme	
Consideration	**Description**
Persons "not normally exposed"	• Project management team require access to area on weekly basis – define these as non-classified workers – Quarterly TLD issued, and criticality locket and visitor PAS signed out when visiting areas under written arrangements.
Data / records storage and infrastructure requirements	• Due to large number of staff and frequency of dosimetry issue, an IT database system would be beneficial as a means of tracking and storing large numbers of records. • Records will need to be backed up on either redundant servers or removable media such as CD.
Reporting method and frequency	• Changing radiation environment due to decommissioning operations requires frequent assessment of doses. • Passive legal dosimetry/bioassay requires time to be analysed, hence this may be reported monthly. • Electronic non-legal dosimetry may be networked such that task-based dose reporting can be automatically generated on a weekly or even daily basis via IT user interface
Company dose objectives and limits	• Based on planned operations in coming year, and knowledge of the radiation dose-rates and contamination present in the areas, the RPA should estimate the annual maximum /average individual and collective doses, to be used as a dose objective and to help ensure dose reduction and ALARP practices. • Due to changing source-terms as decommissioning progresses, dose estimates will need to be regularly reviewed.

Table 14: Example B: Small-scale site radiography cell, review following purchase of new source	
Consideration	**Description**
Nature of the radiological hazard	• **CURRENT SOURCE** – 100kV$_{max}$ continuous output x-ray set, 100mSv/minute @ 1m • **NEW SOURCE** – 1TBq Ir192 installed radiography source
Persons affected by the undertaking	• Radiographers x 4 • Other site (non-radiation worker) personnel external to radiography cell x 20
Work environment	• Interlocked radiography cell • Radiographers only use sources listed above and only undertake radiography within this cell.

Table 14: Example B: Small-scale site radiography cell, review following purchase of new source	
Consideration	**Description**
Existing radiological controls	• Interlocked fail-to-safe access system • Illuminated signage • Cell is a controlled (exclusion) radiation area during radiography • Cell is a supervised radiation area when radiography not being undertaken • No contaminated items are radiographed.
Foreseeable accident scenarios	• Failure of interlocks allows person to be in cell when source exposed/ x-ray set operating • New Ir192 source does not retract properly into shielded container, recovery of source to safe-state required.
Minimum detectable dose required	• 10 μSv whole body dose
Type of dosimetry	• Monthly whole body TLD dosimetry supplied through contract with an external (suitable) ADS. • **Suitability of this ADS and the current provided dosimetry will need to be undertaken prior to use of the new radiography source.** • Electronic dosemeters used on re-entering post-exposure as a means of ensuring sources are safe.
Classification of workers	• Radiography workers = classified persons • Other site personnel = No status required
Visitors and outside workers	• Visitors are not permitted access to radiography cell until sources have been proven safe by radiography team, therefore no visitor dosimetry arrangements required. • Radiography sources are maintained by the equipment manufacturers. Subject to their own dose management arrangements, working within constraints of the site local rules, written arrangements and systems of work.
Persons “not normally exposed”	• Radiography cell designed to reduce dose-rates external to the cell to < minimal detectable activities above background. No dose management required for other site personnel.
Data / records storage and infrastructure requirements	• Dose management infrastructure on the site RPA who collates and tracks doses, in conjunction with the radiography RPS as reported by the external ADS. • Records are stored as paper copies in a secure filing cabinet. Master copies are held by the external ADS.
Reporting method and frequency	• External contract ADS sends paper copies of the legal dose reports on a monthly basis to the site RPA via recorded mail.

Table 14: Example B: Small-scale site radiography cell, review following purchase of new source	
Consideration	**Description**
Company dose objectives and limits	• Based on dose-rates of radiography sources and estimated number of exposures per year, the RPA may set dose targets for the year. • If doses are markedly different than predicted, this can be used as a warning that the radiography arrangements must be reassessed, • Any dose targets will need to be reviewed, should the scope of work for the radiography team changes, or new sources procured.

DEFINITIONS AND ABBREVIATIONS

Accident Dosemeter	Personal dosemeter issued to an individual to record accident related doses in accordance with IRR99 Regulations 12 and 23. See also Special Accident Dosemeter
Accidental Exposure	An exposure of individuals as a result of an accident. It does not include emergency exposure
ACoP	Approved Code of Practice
Acute Exposure	Acute radiation exposure is an exposure to ionizing radiation which occurs during a short period of time
ADS	HSE Approved Dosimetry Service, IRR99 Regulation 2
Agency Worker	Self employed person, that may be recruited and managed via an agency, that the licensee or external employer treats, for health and safety purposes, as an employee
ALARP	As Low As Reasonably Practicable, IRR99 Regulation 8
Algorithm	Is a process or set of instructions which can be represented by a mathematical expression or series of expressions. In individual monitoring, it describes a procedure whereby the output signals from more than one detector are combined to give the indication
ALI	Annual Limit of Intake
AP	Antero-Posterior
APD	Active personal dosemeter - a personal dosemeter which has powered electronic circuitry, usually battery, with associated software and/or firmware, and normally with visible or audible indication of integrated dose and/or dose rate
Appointed Doctor	A registered medical practitioner who is for the time being appointed in writing by the HSE for the purposes of carrying out classified person medicals and advising radiation employers
BSS	Basic Safety Standards [EU 1996a, IAEA 1996]
Calendar Year	Period of twelve months beginning with the 1st January
Chronic Exposure	Exposure to ionizing radiation over an extended period of time is called chronic exposure
CIDI	Central Index of Dose Information – a national register

Classified Person	As defined at Regulation 20 of IRR99
Controlled Area	An area designated in accordance with IRR99 Regulations 16 to 19
DAC	The derived air concentration is defined as that air concentration of a radionuclide that if breathed for a working year, would cause a person to receive the annual limit of intake (ALI) for that radionuclide
DACh	Derived Air Concentration Hours: For example, the DAC for Pu239 is ALI (inhalation) = 20mSv/8.3x10^{-6} Sv/Bq = 2400 Bq DAC = 2400Bq/(1.2m^3/hour x 2000 hours) = 1Bq/m^3 The DAC-hour (DACh) is the time-integrated air concentration that a person has been exposed to. i.e. for example, for a person spending 2 hours in an atmosphere of concentration 1 DAC: DACh = 1 DAC x 2 hours = 2 DACh Therefore 2000 DACh is equivalent to 1 ALI.
Deterministic Effect	In which above a certain threshold dose the severity of the effects increases with increasing dose.
DIS	Direct Ion Storage dosemeter
Dose Equivalent	At a point in tissue is obtained from absorbed dose at the point by multiplying it by the quality factor
Dose History	Record of radiation personal dose received as result of exposure to ionising radiation as a non-classified worker as part of their employment
Dose Record	Record of radiation personal dose received as result of exposure to ionising radiation as a classified person as part of their employment
Dosemeter	A radiation monitoring device to record radiation dose. There are many different types of dosemeter
E	Effective dose (Sv)
Effective Dose	An indicator of the effects of radiation on the body as a whole when different body tissues are exposed to different levels of equivalent dose
Emergency Dosemeter	Dosemeters supplied by an ADS for the purposes of assessing doses from external radiation, issued to record dose related to intervention actions during a radiation emergency

Emergency Exposure	An exposure of individuals implementing the necessary rapid action to bring help to endangered individuals, prevent exposure of a large number of people or save a valuable installation or goods, whereby one of the dose limits equal to that laid down for exposed workers could be exceeded (applicable to volunteers only) The Radiation (Emergency Preparedness and Public Information) Regulations 2001 (REPPIR)
Employer	An employer is a person or organization that hires people to perform work in exchange for compensation, which is usually money in the form of wages or a salary. See also Site Employers Dosimetry Arrangements, External Employer, Radiation Employer and Site Employer definitions below
EURADOS	European Radiation Dosimetry Group (http://www.eurados.org/) EURADOS WG2 EURADOS Working group on Harmonization of Individual Monitoring in Europe (http://www.eurados.org/)
eV	Electron volt (1 eV = $1.60217646 \times 10^{-19}$ joules) unit of energy
Exposed Worker	As defined within BSS - a person either self-employed or working for an employer who is subject to an exposure incurred at work and liable to result in doses exceeding one or other of the dose levels equal to the dose limits for members of the public
External Employee	The employee of an external employer, including contractors employees
External Employer	Any employer other than the site employer, see definition below
External Exposure	Exposure to ionising radiation coming from outside the body of a person
External Radiation	Ionising radiation coming from outside the body of a person
Extremity Dosemeter	Device supplied by an ADS and used to measure extremity dose (e.g finger doses to individuals)
GPG	Good Practice Guide
Gy	Gray, SI unit of absorbed dose (joule per kilogram, $J.kg^{-1}$)
H'(d)	Directional dose equivalent at a depth of d mm in tissue (Sv)
H*(d)	Ambient dose equivalent at a depth of d mm in tissue (Sv)
Health Physicist	Professionally qualified individual working in the field of Health Physics

Health Physics	Field of science concerned with radiation physics and radiation biology with the goal of providing technical information and proper techniques regarding the safe use of ionizing radiation
Health Record	Record of medical surveillance of individual radiation workers
Hp(d)	Personal dose equivalent at a depth of d mm in tissue (Sv)
HSE	Health and Safety Executive (http://www.hse.gov.uk/)
H_T	Tissue equivalent dose (Sv)
IAEA	International Atomic Energy Agency (http://www.iaea.org/)
ICRP	International Commission on Radiological Protection (http://www.icrp.org/)
ICRU	International Commission on Radiation Units and Measurements (http://www.icru.org/)
IDEAS	General Guidelines for the estimation of committed effective dose from incorporation of monitoring data - IDEA (Internal Dosimetry – Enhancements in Application [58]
IEC	International Electrotechnical Commission (http://www.iec.ch/)
in vitro Monitoring	Indirect measurement in an artificial environment outside the body. Typically excreta samples
in vivo Monitoring	Direct measurement providing an estimate of activity within the whole body, or in a region of the body, at the time of monitoring
Internal Exposure	Radiation exposure related to intakes of radioactive material
Internal Radiation	Ionising radiation, in relation to a person, coming from inside the body of the person
Intervention	As defined within REPPIR - A human activity that prevents or decreases the exposure of persons to radiation from a radiation emergency or from an event which could lead to a radiation emergency, (see Emergency Exposure)
Intervention Dose	See Emergency Exposure
Ionising Radiation	The transfer of energy in the form of particles or electromagnetic waves of a wavelength of 100 nanometres or less or a frequency of 3 $x10^{15}$ hertz or more capable of producing ions directly or indirectly
IRPCG	Industry Radiological Protection Co-ordination Group established by and on behalf of the SDF
IRR99	Ionising Radiations Regulations 1999

ISO	Iso Directional
ISO	International Organization for Standardization (http://www.iso.org/)
K_{air}	Kerma in air (Gy)
K_T	Kerma in tissue (Gy)
LAT	Lateral
LET	Linear Energy Transfer (keV/μm)
Licensee	Licensee of a Nuclear Licensed site as defined and described within the Nuclear Installations Act 1965
Medical Exposure	Exposure of a person to ionising radiation for the purpose of their medical or dental treatment or examination
Medical Review/Assessment	Periodic review of health of a radiation worker, conducted by Appointed Doctor. The format for review is a matter of judgement on part of the Appointed Doctor, but will include review of individual's radiation dose profile and sick absence. The review may also include a medical examination and tests as detailed IRR99 Regulation 24
Non-Classified Worker	IRR99 Regulation 18 states that non-classified persons may be employed within radiologically controlled areas in accordance with suitable written arrangements, such persons are referred to as non-classified workers
NORM	Naturally Occurring Radioactive Material
Notional Dose	IRR99 Regulation 22 (1b) - Estimated dose relating to lost, damaged or destroyed dosemeter or dose assessment where it is not practicable to estimate the dose received. The proportion of the total annual dose for the relevant period is utilised as the 'Notional Dose'
NPL	National Physical Laboratory (http://www.npl.co.uk/)
NRRW	National Register of Radiation Workers - a national register
ONR	Office of Nuclear Regulation
OSL	Optically Stimulated Luminescence
Outside Worker	IRR99 Regulation 2(1): Classified person who carries out service in the controlled area of any employer (other than the controlled area of their own employer
PA	Postero-Anterior
PADC	Polyallydiglycol carbonate – material used within a form of neutron dosemeter

Passive Personal Dosemeter	Personal dosemeter that does not have powered circuitry or inbuilt software and/or firmware
Personal dosemeter	A radiation monitoring device to record personal radiation, such as Hp_{10} and $Hp_{0.07}$
PMMA	Polymethylmethacrylate – material used to mimic body mass, such as required for dosimetry phantoms
PRA	Prior Risk Assessment – IRR99 Regulation 7(1): Before a radiation employer commences a new activity involving work with ionising radiation he shall make a suitable and sufficient assessment of the risk
Practice	IRR99 Regulation 2(1): work involving the production, processing, handling, use, holding, storage, transport or disposal of radioactive substances or the operation of electrical equipment emitting radiation and containing components operating at a potential difference of more than 5kV
Quality Factor	Is a measure of the biological effectiveness of the type of radiation as measured by its LET (linear energy transfer) which is the energy lost by a charged particle along its track, per track length. The dependence of quality factor on LET is given in [ICRP 103]
Radiation Accident	REPPIR and IRR99: An accident where immediate action would be required to prevent or reduce the exposure to ionising radiation of employees or any other persons and includes a radiation emergency
Radiation Emergency	REPPIR: Any event (other than a pre-existing situation) which is likely to result in any member of the public being exposed to ionising radiation arising from that event in excess of any of the doses set out in Schedule 1 of REPPIR
Radiation Employer	Employer who, in the course of a trade, business or other undertaking, carries out work with ionising radiation. It includes an employer requiring an employee to enter a Nuclear Licensed Site Controlled Area as part of that employment. Includes self-employed individuals who shall be deemed as both external employer and external employee of the company
Radiation Passbook	A document, approved by the HSE or other national competent authority, supplied by an ADS to the employer, carried by outside workers which includes a summary of the doses received by an individual in the current year. Facilitates the circulation of workers in different countries and contains radiation protection information for example the worker's identification, medical classification and the results of monitoring (dose values received)

Radiation Work	A practice (as defined above) or work in places where radon gas concentration exceeds the values within IRR99 Regulation 3(1) or work with NORM where their use may lead to an effective dose of 1mSv/y
RADS	Requirements for the Approval of Dosimetry Services by the HSE
RBE	Relative Biological Effectiveness: The relative biological effectiveness of an ionising radiation type is a function of radiation energy and particular biological endpoint, and is a relative measure of physiological damage when compared with reference 250keV X-Rays. The biological endpoint is the particular physiological effect being measured, for example, 2MeV neutrons may have two different RBE values depending on whether the physiological effect of interest is skin erythema and alveolar pneumonitis.
REPPIR	The Radiation (Emergency Preparedness and Public Information) Regulations 2001
ROT	Rotational
RPA	Radiation Protection Adviser as defined within IRR99
RPE	Respiratory protective equipment: devices such as respirators and breathing apparatus designed to prevent individuals inhaling hazardous substances such as airborne particulate activity
RPI	Radiation Protection Instrumentation
RPS	Radiation Protection Supervisor as defined within IRR99
SAS	Static Air Sampling
SDF	Nuclear Industry Safety Directors Forum
SI	International System of units or Système International d'unités (http://www.bipm.org/en/si/si_brochure/general.html)
Significant Exposure	As defined at IRR99 ACOP 20(3) exposure is significant if the employee is likely to receive an effective dose at a rate exceeding 1 mSv per year
Site Employer	Nuclear Site Licensee or an operator of a similar large nuclear facility/practice, who is the radiation employer for the specific site or practice
Site Employers Dosimetry Arrangements	Staff and facilities involved with or supporting the site employer's dosimetry provision on a licensed or similar radiological site. May be made up of one of more offices, with any number of staff located in a number of locations, but is referred to within this Guide in the singular

Special Accident Dosemeter	Accident Dosemeter utilised to records dose in circumstances where a dose to the wholebody greater than 0.5 gray might be received as a result of an accident, occurrence or incident
Statement of Service	ADS Statement of Service: a document that the HSE require an ADS to generate as part of the HSE approval process
Sv	Sievert, SI unit of dose equivalent and effective dose
Threshold dose	A reading at the limit of detection of a dosemeter
TLD	Thermoluminescence dosemeter
UKAS	United Kingdom Accreditation Service
Visitor	Visitors, this term is not recognised within IRR99, but is commonly used within the UK nuclear industry and has varying definitions. Visitors may include members of the public, non-classified workers and classified persons
WELMEC	European Legal Cooperation in Legal Metrology. WELMEC is a co-operation between the legal metrology services of the Member States of the European Union European Free Trade Association (EFTA) member states. http://www.welmec.org
Woman of Reproductive Capacity	A woman who is made subject to the additional dose limit for a woman of reproductive capacity by an entry in her health record made by an appointed doctor
Working Year	The number of hours worked in the radiological environment in a calendar year. Also equivalent to the maximum exposure duration by a worker in a calendar year. Where possible, the value used should be specific to the person/ workplace of interest. In the absence of this information, a default of 2000 hours per year should be used (40 hours per week x 50 weeks per year which is assumed to be a conservative).
w_R	Radiation weighting factor
w_T	Tissue weighting factor

REFERENCES

1. Ionising Radiation Regulations SI 1999/3232 Stationery Office 2000
2. Working with Ionising Radiation, The Ionising Radiations Regulations 1999, Approved Code of Practice and Guidance, HSE Books 2000, http://www.hse.gov.uk/pubns/priced/l121.pdf
3. Radiation (Emergency Preparedness and Public Information) Regulations 2001 SI 2001/2975 Stationery Office 2001
4. A Guide to Radiation (Emergency Preparedness and Public Information) Regulations 2001 SI 2001, HSE Books 2002, http://www.hse.gov.uk/pubns/priced/l126.pdf
5. HSE Statement on the Approval of Dosimetry Services, April 2009
6. RADS 1 - HSE Requirements for the Approval of Dosimetry Services under the Ionising Radiations Regulations 1999 - Part 1 - External Radiations, HSE 2008
7. Supplement on Approval for Emergency Exposures during Intervention, Health and Safety Executive 2003.
8. Requirements for the Approval of Dosimetry Services under the Ionising Radiations Regulations 1999: Part 2 Internal Radiations. RADS 2 (revised 2004).HSE
9. Ionising Radiations Regulations 1985 – Guidance on individual monitoring of internal radiation from the prolonged retention of long lived radionuclides (revised 1998). HSE 1998
10. HSE Information Sheet – "Radiation doses – Assessment and Recording' – Ionising radiation Protection Series 2 (revised) 03/2000
11. Nuclear Installations Act 1965, Stationery Office
12. The Carriage of Dangerous Goods and Use of Transportable Pressure Equipment Regulations 2009, Stationery Office 2009
13. European Agreement Concerning the International Carriage of Dangerous Goods by Road, January 2009 (ADR),
14. European Commission, Directorate-General for Energy and Transport Directorate H Nuclear Energy Unit H.4, Radiation Protection No 160, 2009, Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation. (http://ec.europa.eu/energy/nuclear/radiation_protection/doc/publication/160.pdf)
15. HSE, Research Report 385 - Adequacy of external dosimetry methods and suitability of personal dosemeters for workplace radiation fields, http://www.hse.gov.uk/research/rrhtm/rr385.htm
16. ISO 4037-1 International Organization for Standardization X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 1: Radiation characteristics and production methods ISO 4037-1 (ISO: Geneva) (1996)
17. ISO 4037-2 International Organization for Standardization X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response as a function of photon energy – Part 2: Dosimetry for radiation protection over the energy ranges from 8 keV to 1,3 MeV and 4 MeV to 9 MeV ISO 4037-2 (ISO: Geneva) (1997)
18. ISO 4037-3 International Organization for Standardization X and gamma reference radiations for calibrating dosemeters and dose rate meters and for determining their response as a function of photon energy, Part 3: Calibration of area and personal dosemeters and the measurement of their response as a function of energy and angle of incidence. ISO 4037-3. (ISO: Geneva) (1993).
19. ISO 4037-4 International Organization for Standardization X and gamma reference radiation for calibrating dosemeters and doserate meters and for determining their response

as a function of photon energy – Part 4: Calibration of area and personal dosemeters in low energy X reference radiation fields ISO 4037-4 (ISO: Geneva) (2004).

20. ISO 6980-2 International Organization for Standardization, Nuclear energy – Reference beta-particle radiation – Part 2: Calibration fundamentals related to basic quantities characterizing the radiation field ISO 6980-2 (ISO: Geneva) (2004).
21. ISO 6980-3 International Organization for Standardization, Nuclear energy – Reference beta-particle radiation – Part 3: Calibration of area and personal dosemeters and the determination of their response as a function of beta radiation energy and angle of incidence ISO 6980-3 (ISO: Geneva) (2006).
22. ISO 9000-1 International Organization for Standardization Quality management and quality assurance standards, Part 1: Guidelines for selection and use. ISO 9000-1 (ISO: Geneva) (1994).
23. ISO 14146 International Organization for Standardization Radiation protection – Criteria and performance limits for the periodic evaluation of processors of personal dosemeters for X and gamma radiation. ISO 14146. (ISO: Geneva) (2000).
24. BS EN ISO/IEC 17025:2005 General requirements for the competence of testing and calibration laboratories
25. ISO 20553:2006 Radiation protection -- Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material
26. ISO/DIS 27048: 2009 Radiation protection -- Dose assessment for the monitoring of workers for internal radiation exposure.
27. ISO 28218: 2010 Radiation Protection - Performance Criteria for Radiobioassay
28. ICRP Publication 30: Limits for Intakes of Radionuclides by Workers - Part 3
29. ICRP Publication 56: Age-dependent Doses to Members of the Public from Intake of Radionuclide's – Part 1
30. ICRP Publication 60: 1990 Recommendations of the International Commission on Radiological Protection
31. ICRP Publication 66: Human Respiratory Tract Model for Radiological Protection
32. ICRP Publication 67: Age-dependent Doses to Members of the Public from Intake of Radionuclide's - Part 2 Ingestion Dose Coefficients
33. ICRP Publication 68: Dose Coefficients for Intakes of Radionuclides by Workers
34. ICRP Publication 69: Age-dependant Doses to Members of the Public from Intake of Radionuclide's – Part 3 Ingestion Dose Coefficients
35. ICRP Publication 71: Age-dependant Doses to Members of the Public from Intake of Radionuclide's – Part 4 Inhalation Dose Coefficients
36. ICRP Publication 75: General Principles for the Radiation Protection of Workers.
37. ICRP Publication 78: Individual Monitoring for Internal Exposure of Workers
38. ICRP Publication 85: Avoidance of Radiation Injuries from Medical Interventional Procedures
39. ICRP Publication 89: Basic Anatomical and Physiological Data for Use in Radiological Protection: Reference Values
40. ICRP Publication 100: Human Alimentary Tract Model for Radiological Protection
41. ICRP Publication 103: The 2007 Recommendations of the International Commission on Radiological Protection
42. Documents of the NRPB, Assessment of Skin Doses, Vol 8 No.3 1997, MP Little, MW Charles, JW Hopewell, A Mayall, DC Lloyd, AA Edwards, C Sharp, and JR Hooper
43. Calculation of the Dose to the Basal Layer of Skin from Beta/Gamma Contamination, A.R Curran, Journal of Society of Radiological Protection 6(1) 1986.
44. IAEA-TECDOC-1162 – Generic procedures for assessment and response during a radiological emergency. Skin Contamination: To assess skin beta dose from material deposited onto skin or clothing.
45. Radionuclide and Radiation Protection Data Handbook 2002, D Delacroix, JP Guerre, P Leblanc, C Hickman

46. The 'Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities DOE-STD-1128-98'
47. ISO/FDIS 15382 Nuclear Energy – Radioprotection – Procedure for radiation protection monitoring in nuclear installations for external exposure to weakly penetrating radiation, especially to beta radiation
48. IAEA Safety Standards Series – Assessment of Occupational Exposure Due to External Sources of Radiation
49. Radiation Doses – Assessment and Recording - http://www.hse.gov.uk/pubns/irp2.pdf
50. Poster on wearing dosimetry – http://www.hse.gov.uk/pubns/indg207.pdf
51. HSE Approved Dosimetry Service - http://www.hse.gov.uk/radiation/ionising/dosimetry/ads.htm
52. RR385 – Adequacy of external dosimetry methods and suitability of personal dosemeters for workplace radiation fields - http://www.hse.gov.uk/research/rrhtm/rr385.htm
53. HSE Information on doses - http://www.hse.gov.uk/radiation/ionising/doses/index.htm
54. Protection of Outside Workers against Ionising Radiation – http://www.hse.gov.uk/pubns/irp4.pdf
55. Appropriate Designation of Classified Persons - http://www.hse.gov.uk/radiation/ionising/doses/designation.htm
56. Numerical targets and legal limits in Safety Assessment Principles for Nuclear Facilities - http://www.hse.gov.uk/nuclear/saps/explanation.pdfl
57. AEA Safety Standards Series Safety Guide No. RS-G-1.3: Assessment of Occupational Exposure due to External Sources of Radiation - http://www.citon.ro/pncdi_ii_web/16B.pdf
58. IDEAS - General guidelines for the estimation of committed effective dose from incorporation monitoring data (Project IDEAS - EU Contract No. FIKR-CT2001-00160) Report FZKA 7243 Forschungszentrum Karlsruhe H Doerfel, A Andrasi, M Bailey, V Berkovski, E Blanchardon, C-M Castellani, C Hurtgen, B LeGuen, I Malatova, J Marsh, J Stather
59. Personal Dosimetry Trial at Devonport Royal Dockyard, J. Radiol. Prot. 25, pp1-32, (2005), R Collison
60. Extremity Dosimetry Trial: Devonport Royal Dockyard, Radiation Protection Dosimetry (2008), R Kenyons, R Collison
61. Overview of double dosimetry procedures for the determination of effective doses to interventional radiology staff. Radiation Protection Dosimetry. 129 (1-3), pp333-339. 2008 Jarvinen, H. Buls, N. Clerinx, P. et al.
62. An overview of extremity dosimetry in medical applications. Radiation Protection Dosimetry. 129 (1-3), pp350-355. 2008 Vanhavare, F. Carinou, E. Donadille, L. et al.
63. Deposition and clearance of inhaled particles in the human nasal passage: Implications for dose assessment. Radiat. Prot. Dosim, G Etherington et al. 79, 249-252 (1998)
64. Implications of volunteer nasal deposition and clearance studies for the dosimetry of the extrathoracic airways of the respiratory tract NRPB-M1220, Smith, J R H, Eastham, B and Etherington, G.December 2000
65. The removal of particles from the nasopharangeal (NP) compartment of the respiratory tract by nose blowing and swabbing. Hounam, R F. Health Physics, 28, 743-750 (1974)
66. Guidance on the Application of Dose Coefficients for the Embryo, Fetus and Breastfed Infant in Dose Assessments for Members of the Public, Advice from the HPA, March 2008.
67. Working Safely with Ionising Radiation Guidelines for Expectant or Breastfeeding Mothers, HSE Publications, March 2001
68. Doses to the Embryo/Fetus and Neonate from Intakes of Radionuclides by the Mother, parts 1 and 2. NRPB for HSE, Contract Research Report 397/2001, 2001

Annex 1 List of Personal Dosimetry Good Practice Guide Working Group Members

GPG Working Group members at time of Personal Dosimetry GPG Development

Roger Collison	Babcock International Group - Chair/Editor
John Bradshaw	AWE Plc
Daniel West	AWE Plc
Anthony Ridgley	Dounreay Site Restoration Limited
Simon Morris	EDF Energy Nuclear Generation
Andrew Corns	GE Healthcare Ltd
Sarah Sanders	Magnox Limited
Paul Stock	Ministry of Defence
Graham Wilkins	Rolls-Royce
Lesley Hales	Rolls-Royce
Christine Wilson	Sellafield Limited
Marie Barnes	Babcock International Group - Secretary/Editor

Annex 2 Ionising Radiation Regulation 1999 – Dosimetry Drivers

The legal requirements and drivers related to dosimetry management are detailed mainly within the Ionising Radiations Regulations 1999 (IRR99) [1, 2]. The key employers dosimetry requirements and drivers are summarised within this annex. The wider drivers are described within chapter 2

Duties on the Employer: Regulation 4 – see chapter 2 section 2.1 and Table 1.

Prior Risk Assessment: Regulation 7 – Before a radiation employer commences work with ionising radiation a suitable and sufficient risk assessment is required. This assessment will include assessment of the requirements related to dosimetry provision either directly or implied by the identification of

- nature of the sources of ionising radiation
- estimated radiation doserates
- likelihood of and levels of airborne and surface contamination
- related existing dosimetry information
- engineering and design measures and requirements
- systems of work
- designation and access requirements related to controlled areas
- accident scenarios
- requirements fore dose controls and constraints
- requirement to designate radiation workers
- dose assessment requirements

Restriction of Exposure: Regulation 8 – The radiation employer has the responsibility of ensuring that exposure to ionising radiation is restricted as far as is reasonably practicable. A key component of monitoring this is by analysis of personal dose data.

Dose Limits: Regulation 11: The employer shall ensure that his employees and other persons are not exposed to ionising radiations to an extent that any relevant dose limit is exceeded in any calendar year. A key component of monitoring this is by analysis of personal dose data.

Dosimetry For Radiation Accidents: **Regulations 12(1), 12(2b) and 23 -** see section 2.2.

Co-Operation Between Employers: Regulation 15 - Where work with ionising radiation undertaken by one employer is likely to give rise to the exposure to ionising radiation of the employees of another employer, the employers concerned shall co-operate by exchange of information. Exchange of dosimetry data is often a key element of this cooperation.

Outside Workers: Regulations 18(2b), 18(4), 21(5), 36 and Schedule 6 – The employer shall ensure that any outside workers working within controlled area under their control, are subject to ADS dose assessment and are certified fit to work with ionising radiation. Arrangements shall be in place to estimate the dose of the worker whilst within the area and that the radiation passbook is updated to reflect that dose. Employers of outside workers shall ensure that each such worker is supplied with a current radiation passbook and that the radiation passbook is kept up to date.

Non-Classified Workers: Regulations 18(2c) and 18(3) – An employer can only employ persons to work within radiological controlled areas who are either classified persons or non-classified workers subject to specific written arrangements. The employer has to demonstrate that doses to the non-classified workers are restricted in accordance with the written arrangements: this is normally achieved by personal dose monitoring.

Classified Persons: Regulation 20(1 to 3) – The employer shall designate as classified persons employees who may receive an effective dose greater than 6mSv or an equivalent dose which exceeds three tenths of any relevant dose limit. The person shall be 18 years or over and be certified fit for such work by the appointed doctor. The employer may cease to treat an employee as a classified person only at the end of a calendar year except where the appointed doctor requires the classification to cease or the employee cease their employment or if the employee is no longer employed in a capacity which is likely to result in a significant exposure to ionising radiation (1mSv in the calendar year).

Dose Assessment and Recording: Regulations 21 and 18(5) – the employer is required to measure and assess all doses of ionising radiation, for employees designated as classified persons, which are likely to be significant and to ensure these are recorded. Records relating to the personal dose monitoring and assessment arrangements for non-classified workers shall be retained for two years. The employer shall also make arrangements with one or more HSE Approved Dosimetry Service (ADS) for:

- making systematic assessment of these doses by measurement or other suitable means
- making and maintaining dose records. Such records shall be retained until the individual has attained the age of 75 years or for at least 50 years from when the record was created, whichever is the greater

Estimated Doses and Special Entries: Regulation 22 – the employer shall make adequate investigation of the circumstances of any discrepancy related to the dose measurement (loss, damage etc) with a view to estimating the dose received, informing the ADS and classified person of the results. Where an employer has reasonable grounds to believe that the dose recorded is much more or less than that received shall advise the ADS and classified person of the details and related investigation. This shall be subject to HSE review and agreement where a relevant dose limit may have been exceeded.

Medical Surveillance: Regulation 24 – The employer shall ensure that suitable medical surveillance, by an appointed doctor, is available for each employee employed as a classified person or other employees engaged in radiation work that are subject to conditions imposed by the appointed doctor. Such medical surveillance should include

- medical examination before being designated as a classified person
- periodic review, at least annually
- special medical surveillance when a relevant dose has been exceeded
- determining whether specific conditions are required

Overexposure: Regulations 25 and 26 – Where an employer suspects or has been informed that any person has exceeded a limit this shall be investigated and verified. The Regulator, relevant employer(s) and appointed doctor shall be notified. The individual shall be informed and a record of the investigation added to the individual's dose record and provided to the individual. A proportional dose limit may be applied to the individual for the remaining calendar year or other appropriate period.

Duties of Employees: Regulation 34 – Employees have duties to look after themselves, other workers, their safety equipment including dosimetry equipment/records and to follow the reasonable requests of the employers with regards to these matters.

Approval of Dosimetry Services: Regulation 35 – The HSE approve dosimetry services by assessing the service and issuing certificates that are reviewed and updated periodically. The HSE requirements for such approval are set out within RADS (Requirements for the Approval of Dosimetry Services by the HSE) [5, 6]. In order to obtain approval under IRR99 and REPPIR, a dosimetry service must be able to meet certain criteria specified by HSE these include requirements related to normal operational dosimetry, foreseeable over exposures and those required in accident and emergency circumstances. See sections 2.2, 2.4 and chapter 6.

Annex 3 Personal Dosemeters – Dual Wear

Site and external employer's arrangements may require radiation workers to wear more than one personal dosemeter to measure the same radiation dose. The majority of such cases relate to photon dosimetry, but can be relevant for any form of dosimetry. This annex looks predominately at whole-body photon dosimetry using passive and APD, but the issues raised can be as relevant for other forms of dosimetry such as whole-body neutron/beta or extremity dosimetry.

The requirements for dual wear of personal dosimetry can include:

- Providing a combination of local dose control and legal record, such as use of an APD to supply immediate visual and audible indication of dose with an ADS supplied passive dosemeter as part of an approved dosimetry system
- An external employer utilising a passive ADS supplied dosemeter to measure, assess and record dose accrued by their employee when visiting other employers' radiological areas. APD may also be used by the site employers to record dose received on their sites by the external employee
- Uncertainty as to accuracy of a particular type of dosemeter measurement or assessment requiring a second dosemeter of another type to provide a back-up and reassurance measurement

It is good practice for the site employer to include in the assessment described at chapter 4 details of how each dosimetry arrangement will respond in actual operational circumstances. From this the site employer should be able to establish the ranges of uncertainties expected for each dosemeter utilised on the site, including typical dosemeters utilised by external employer's staff. It is to be expected that each dosemeter type and assessment methodology will respond differently, particularly their typical photon energy response. So there will also be systematic differences in typical dual wear dosemeters, these anticipated differences should be documented and communicated, particularly to external employers and area operators so that any apparent differences can be understood and managed.

Where dual wear occurs the employer should conduct a comparison of results obtained to identify significant unexpected differences. Comparison of results may be by a manual process, however most modern dosimetry software, as described at chapter 6, should be able to automate this process. To conduct the checks various parameters will need to be established from the assessment described at chapter 4. These parameters will include the expected range of differences and a threshold value below which it is not considered worthwhile to investigate discrepancies. For example a site dominated by direct and indirect Cobalt-60 photons with typical monthly personal doses of up to 1mSv may set an initial cut off of doses at less than 0.1mSv and differences of monthly totals of 10% between site APD and passive photon dosemeters. All differences outside this range will be investigated and justified or amended. The site employer should conduct these checks for site employees and liaise with external employers as necessary to allow them to conduct similar checks.

Where ADS passive and local APD are utilised in conjunction within a dual wear programme arrangements will be required to ensure:

- The normal operational day to day dose as measured by the APD, recorded on the site dosimetry system is accurately understood
- The likely ratio between ADS passive and APD is known and understood
- That the APD assessed and recorded dose is an accurate estimate of the ADS passive dosimetry assessed and recorded result

The employer will need to ensure that any significant differences between the locally recorded dose and the dose measured, assessed and recorded via the approved dosimetry system does not lead to individuals inadvertently exceeding a dose limit or constraint. A number of measures will be required, including:

- Specific calibration of dosimetry so as to match or slightly exceed the response of the dosimetry measuring, assessing and recording the legal dose
- Update of the site system when passive dosimetry results are received. This will include either automated update of annual running totals or checks against pre-set values that ensure individuals can not exceed a dose limit or constraint
- Review of all passive badge results and comparison to criteria noted above, this will often be an automated part of the site software
- Statistical analysis of results to identify trends, particularly endemic problems
- During high profile or high dose rate tasks special arrangements being agreed between employers, such as agreeing use of a single common dosemeter and suspending dual wear dosimetry arrangements

The effect of significant differences between dual wear dosimetry on individual workers should not be underestimated. The site and external employers will need to justify the recorded final dose, explaining the reasons for any significant differences between dosimetry results and allay individuals concerns. The time and resource required to support this should not be underestimated.

Annex 4 Operational Dose Quantities Approximations

Real-world personal dosemeters for external radiation cannot directly measure the protection quantities: effective dose E and tissue equivalent doses HT (e.g. HEyeLens), despite these being the quantities required for legal dose control. Instead, it is widely adopted that ADSs generally measure the personal dose equivalent operational quantities, Hp(d) – in particular, Hp(10), Hp(0.5), Hp(0.07) and Hp(3) – at standard dosemeter wear positions on the body, and use these as approximations for E and HT. These are termed the 'operational dose quantity approximations', and are as described below:

- **Effective dose, E,** is to be assessed by a trunk-worn dosemeter designed and calibrated to measure Hp(10).
- **Equivalent dose to local skin, H_{skin},** (maximum value to the skin, averaged over 1 cm^2) is, in the case of photons and electrons, to be assessed by dosemeters worn at the skin area of greatest concern which are designed and calibrated to measure Hp(0.07). For neutrons, Hskin, is to be assessed by dosemeters worn at the skin area of concern which are designed and calibrated to measure Hp(10).
- **Equivalent dose to an extremity, H_{ext} (e.g. H_{hand})**, is approximated by the equivalent dose to local skin on the extremity, summed for all components, and is to be assessed by dosemeters worn on the extremities (at the location of greatest concern) which are designed and calibrated to measure Hp(0.07) in the case of photons and electrons, and Hp(10) in the case of neutrons.
- **Equivalent dose to the lens of the eye, $H_{EyeLens}$,** is to be assessed by a forehead-worn dosemeter designed and calibrated to measure Hp(3), or by a combination of a head-worn Hp(0.07) measurement and a trunk-worn Hp(10) measurement.

Importantly, in the basic application of these approximations, the ADS may commit Hp(d) measurements to legal dose records, without correction, as assessments of E or H_T. The accuracy of the approximations (i.e. the true discrepancy between Hp(d) and E or HT) for the radiation types, R, energies, ε, and exposure geometries, Φ (e.g. Φ = AP, PA, LAT, ROT, ISO) comprising most workplace fields is detailed in ICRU 57. This data shows that the approximations are broadly justified because, for most field regions, Hp(d) values slightly overestimate the protection quantities such that, as assessments of E or HT, they are sensibly conservative. However, the graphs also reveal some field regions for which the overestimate is excessive and a few regions for which Hp(d) underestimates E or HT. Though rarely a concern, the employer should address this, by comparison of the workplace field data with the Hp(d)⇔E,H_T functions in ICRU 57, in order to assess (and hopefully to dismiss) the possibility that standard application of the operational dose quantity approximations may themselves result in bad dosimetry.

Example: For workers mainly handling low energy (10-40keV) photon emitters in Φ=AP exposure geometry (e.g. in laboratory bench work with iodine-125 or iodine-129) Figure 59 of ICRU 57 suggests that any trunk-worn dosemeter accurately measuring Hp(10) would overestimate E by a factor of f ≅ 3. In this case, the employer could make arrangements with an ADS to assess E by applying a correction factor to its Hp(10) measurement, i.e. E = Hp(10)/f. Alternatively, if the group for which the overestimate occurs is small in

relation to the whole workforce for which effective dose must be assessed, and particularly if the sub-group's exposures are low, then the employer may choose (for the simplicity and cost-effectiveness of utilising just one Statement of Service for the whole workforce) to make no correction but, instead, to accept the overestimate for the sub-group.

It should be noted that these issues arising from inaccuracies in the operational dose quantity approximations are independent of and supplementary to any dosemeter's performance or inaccuracies in measuring Hp(d): see section 4.2 - and would arise regardless of which dosemeter were considered for the measurement.

Annex 5 Detectors to Determine Hp(10) and Hp(0.07)

Below are summarised the general dosimetry characteristics of detectors used to determine Hp(10) and Hp(0.07) from exposure to external photons this data has been reproduced from HSE guidance ref [10]

Method: Detector	Energy and angle dependence of response characteristics	Linearity, dose rate dependence, detection limit	Effect of other radiation types	Effect of other influence quantities
Film badge: Film emulsion	*H*p(10) and *H*p (0.07) responses within factor of ±2 from 20keV to 6/7 MeV, 0° to 60°, using standard badge and algorithm.	Linear *H*p(10) and *H*p(0.07) response up to 10 Sv. Detection limit is 100 to 200 μSv	Some neutron sensitivity.	Can be susceptible to temperature and humidity.
TL: Li F:Mg,Ti	Response is approximately proportional to photon tissue dose from 10kev to 10Mev, with a max. deviation of +50% (over-response) at c. 30keV if normalized at 667 keV, i.e. calibration with ^{137}Cs. Hp(10) responses within factor of ±1.5 from 10kev to 10Mev with simple plastic filters of thickness c. 1 gm/cm^2 - which also give good angular response. Metallic filters improve energy response but worsen angular response. *H*p(0.07) energy response is also good if minimal covering of the detectors is used, but angular response varies with TL material thickness and the design of the opening in the holders above the detector.	Linear *H*p(10) and *H*p(0.07) response up to a few Sv. No dose rate dependence. Detection limit is a few tens of μSv.	If neutrons are present need to use ^{7}LiF	Little temperature or humidity effects under normal conditions. Fading c. 5% y^{-1}. Responds to UV. Small response to visible light, but worse if incorporated in PTFE matrix. Triboluminescence effects in fine powder form.
TL: LiF:Mg,Cu,P	Better energy dependence of tissue dose response than LiF:Mg,Ti, with a max. deviation of -20% (under-response) at c.200keV relative to ^{137}Cs, therefore easier to design good dosemeter for both *H*p(10) and *H*p(0.07). Same general considerations as for LiF:Mg,Ti, including use of algorithms.	Linear *H*p(10) and *H*p(0.07) response up to tens of Sv. No doserate dependence. Detection limit of a few μSv	If neutrons are present need to use ^{7}LiF	Little temperature or humidity effects. Fading of < 5% y^{-1}. Little visible light sensitivity and lower UV sensitivity than L:F:Mg, Ti.
TL: $CaSO_4$:Dy $CaSO_4$:Tm	$CaSO_4$ has a relatively high effective atomic number. This gives rise to a non-ideal energy dependence of response with a maximum deviation for unfiltered material of about a factor of 1at about 30keV. With appropriate filters used in conjunction with an algorithm, the maximum deviation can be restricted to about ±20% from 17keV up to 3Mev. $CaSO_4$ is approximately 50 times more sensitive than LiF:Mg,Ti	Linear *H*p(10) and *H*p(0.07) response up to 30 Sv. No doserate dependence. Detection limit of a few μSv.	Little neutron sensitivity	$CaSO_4$ shows greater thermal fading (5.to 30% in 6 months) and shows optical fading.
TL: $Li_2B_4O_7$:Mn $Li_2B_4O_7$:Cu	Lithium borate has an effective atomic number close to tissue and therefore a good tissue dose response. However its sensitivity is only about 1/10 that of LiF:Mg,Ti..	Linear *H*p(10) and *H*p(0.07) response up to a few Sv. No doserate dependence. Detection limit of a few tens to 100 μSv.	If neutrons present need to use $^{7}Li_2{}^{10}B_4O_7$	Reasonable fading characteristics, about 30% in a year.
OSL: Al_2O_3:C	Without filtration, the material shows a maximum deviation from a tissue dose response of about a factor of 4 at about 30 keV. High sensitivity.	Linear *H*p(10) and *H*p(0.07) response up to 30 Sv. No doserate dependence. Detection limit of a few μSv.	Little neutron sensitivity	Little fading. Strongly affected by light.
DIS: Air ionization chamber	Direct ion storage detectors are small ionization chambers where energy dependence of response is determined by the walls, and other surrounding materials. Maximum deviation of 15% in range from 15 kev to 9 MeV.	Linear *H*p(10) and *H*p(0.07) response up to 40 Sv. Detection limit of 1 μSv.	Little neutron sensitivity	Generally environmentally robust.

Method: Detector	Energy and angle dependence of response characteristics	Linearity, dose rate dependence, detection limit	Effect of other radiation types	Effect of other influence quantities
APD: Silicon photodiode	Without filtration, the detector shows a maximum deviation of tissue dose response of about 5 at 30 keV. But in a simple configuration of two or three detectors and simple circuitry, a maximum, deviation of ± 20% over the photon range 15 kev to 9 MeV. The lower energy limit is determined mainly by the electronic noise threshold.	Linear *H*p(10) and *H*p(0.07) response up to > 16 Sv. Detection limit of 1 μSv.	Little neutron sensitivity	Generally robust, but note possible effects of impact and electromagnetic fields.
APD: G.M tube - compensated	With compensation by metallic filters, GM tube detectors show a maximum deviation of photon energy dependence of response of about ± 20% for the energy range from about 50kev to 3 MeV.	Linear *H*p(10) and *H*p(0.07) response up to 10 Sv. Detection limit of 1 μSv.	Little neutron sensitivity.	Generally environmentally robust.

Annex 6 Criticality Dosimetry

Criticality accidents deliver most of their dose in very short duration pulsed fields. Neutron detectors worn on the surface of the body respond to both incident neutrons and to those reflected by the body (if the latter has energies within the detection limits of the dosemeter). Gamma ray detectors worn on the surface of the body respond to incident gamma rays, those reflected from the body and those liberated by neutron reactions in the body. The assessment of both gamma and neutron components is highly dependent upon the orientation of the person and the dosemeter to the critical assembly at the time of the accident. However, since it is neutrons with energies greater than 200 keV that usually contribute most of the neutron dose, it is essential to ensure that an accurate measurement of fast neutrons is possible. If the body of the person wearing the dosemeter is between the critical assembly and the dosemeter, the body will attenuate fast neutrons, and the dose recorded by the dosemeter will underestimate the maximum surface absorbed dose to the person by up to a factor of ten. The body will also attenuate gamma rays and the dose recorded by the TLD (other passive) will be reduced by up to a factor of two if exposure is from the rear. Studies have shown that electronic dosemeters can greatly under-respond to pulsed radiation fields.

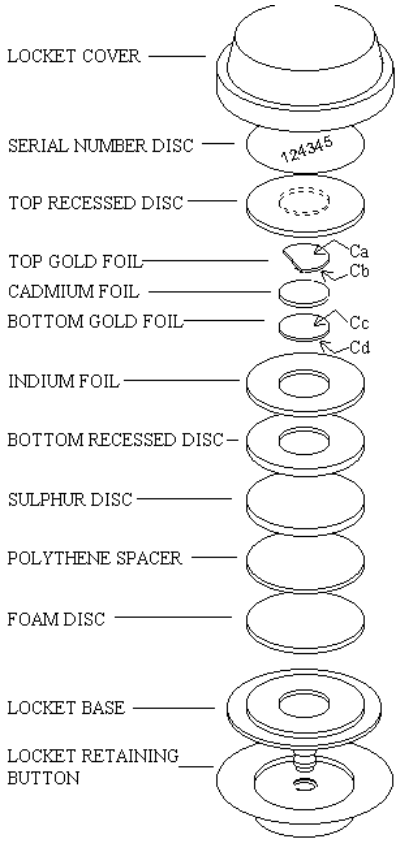

Figure 7: UKAEA Criticality Locket

Personal dosemeter: the criticality locket

UK employers use the UKAEA mark III criticality locket for assessment of criticality related neutron dose, see Figure 1. These lockets are usually mounted on a belt. Multiple lockets are likely to be

required to provide the necessary degree of accuracy in circumstances where the orientation of workers in not known. In the UK, two lockets are normally used, a compromise between cost and accuracy.

The locket contains discs that are activated by incident neutrons. Disc materials have different effective energy thresholds. The indium disc is monitored for activation (due to the 115In (n,γ) 116mIn reaction) for the primary function of rapid identification of individuals requiring urgent medical treatment. However, this is only a crude guide to exposure, and the 115In activation reaction only arises from thermal neutrons. The standard method of assessment for the fast neutron dose is made using the sulphur disc. The standard assessment is then refined (for thermal dose component) by a further indium disc measurement. A body sodium activation measurement (see below) may also be used to refine the dose.

To make measurements on all of the locket components is very time consuming, taking approximately 40 minutes per locket. This can pose a considerable problem in an accident involving more than a few people.

Primary Screening Methods: body 24Na Measurement

A further technique is the of measurement of body sodium activation using handheld Radiation Protection Instrumentation (RPI).

A second screening method can also be used, using activation of ^{23}Na in the body according to the $^{23}Na(n, \gamma)24Na$ reaction Sodium is activated by thermal neutrons, or by neutrons thermalised within the body. The ^{24}Na radioisotope has a half life of 15 hours and can be measured by gamma counting. In the case of immediate measurement after an incident, a correction would be necessary to take account of activities from other activation products (38C1 particularly). Orientation effects are still influential (lateral irradiation may result in 60% of the activation of frontal irradiation), but are less significant than those from activation of indium in the dosemeter since the shielding/moderating effect of the body is removed.

Other Measurements

For the primary function of rapid identification (within 8 hours) of individuals requiring urgent medical treatment (those who may have doses > 1 Gy), the initial use of the indium disc within the criticality locket UK has been mentioned above. Some sites incorporate an indium strip into their routine-issue whole body dosemeters or into site security passes. This is used for the same rapid identification purpose.

Optional silicon diode dosemeters may also be used as part of the criticality belt as an additional method of neutron dose assessment. Gamma dose assessment may be provided using TLD chips attached to the criticality belt, or in some cases, by the routine whole body dosemeter. The ADS will also be able to advise on alternatives to dosemeter assessments such as monitoring for body sodium activation.

Annex 7 Chromosomal Aberration Dosimetry

Where it is identified within the radiological risk assessment that an individual may receive wholebody doses in excess of 100 mSv in a short period of time (day or less) contingency dosimetry assessment arrangements should be identified, documented and put in place. This is a highly specialised field and specialist advice should be sought. One option is Chromosomal Aberration Dosimetry which is available from specialist radio biological laboratories. A small (5-10ml) sample of heparinised blood can be sent by post or courier to the laboratory and a minimum of three working days are needed after receipt of the specimen. Metaphases from T-lymphocytes are prepared and analysed for chromosomal damage caused by radiation. The dicentric aberration is used to indicate exposure because:

- it is easily identified
- it is practically unique to radiation
- it has a low background level (~1 in 1,000 cells)
- it has a highly reproducible dose response relationship that, with a few exceptions, shows little difference between individuals. The level of effect is dependent on radiation type, ie., x-rays: gamma-rays: neutrons and therefore a set of dose response curves, typical of the various radiations commonly encountered in accidents, has been prepared. With x- and gamma-rays the effect is also dependent on the time over which the dose is received and whether it is continuous or intermittent. For unbroken exposures lasting for more than 1 hour or interrupted exposures with gaps of 1 hour or longer some idea of the likely time course of the exposure is needed
- the particular sub-sets of T-cells examined have a fairly long life-span (~3 year half-life) it is possible to carry out the analysis at considerable times after the irradiation. A sampling delay of up to 1 year would not seriously prejudice the assay

The lower limit of dose detection by the chromosomal method is about 100 mGy of X or gamma rays, although at this level there are considerable uncertainties. The results of the test are given as the most likely estimate of averaged whole body dose with 95% confidence limits. The method gives an estimate of dose from penetrating radiation, therefore it is not applicable to exposure from soft x-rays or surface contamination with α or β particles. Non-uniform or partial body irradiations may occur. Sometimes an allowance can be made for this by statistical methods but the technique is not applicable to very localised exposures, e.g. from a very narrow radiation beam or dose just to a hand.

When advising an irradiated person it is worth noting that the presence of aberrations in the blood lymphocytes is in itself of no health consequence. Therefore the technique is a biological dosemeter and not a risk meter.

Annex 8 Dosimetry - Non Uniform Exposures Including PPE Effect

Where there is significant non-uniformity of the radiation field or where protective clothing is worn it may be necessary to use more than one dosemeter to obtain additional measurements to improve the dose measurement. In highly non-uniform radiation fields, additional body and extremity dosemeters should be worn (for example, on the fingers, ankles, knees or head).

Protective equipment should be worn if appropriate, for example gloves, goggles, lead aprons (with/without thyroid shield). When protective equipment is worn, it is essential to correctly position the dosemeter(s):

- Lead apron: double dosimetry is recommended. The dosemeter above the apron should be worn at the collar level, and the result from this dosemeter can be used, in addition, to estimate equivalent dose to the eye lens. The dosemeter under the apron may be worn at the waist or chest, preferably the chest, but a different algorithm will be needed for the different positions. In situations where it is well established that doses are low, it is acceptable to wear only one dosemeter. To obtain the best estimate of E this should be worn under the apron, although a more sensitive indication of changes in the working environment can be achieved with a dosemeter worn on the collar with the application of a correction factor. This approach is less likely to lead to an underestimate of E. For more information reference should be made to ICRP 85 [38] and Järvinen 2008 [61].
- Similar considerations are necessary for eye dosimetry where protective eyewear is worn either for radiation protection or conventional safety reasons.
- In many cases of measurements in non-uniform fields, such as the handling of low energy beta sources, it will not be possible to place a local skin dosemeter or extremity dosemeter at the most highly exposed part which for many procedures where extremity dosemeters are used is frequently the finger tip. Ring, finger stall or wrist dosemeters are commonly worn, and it is presumed that these are worn underneath any gloves or gauntlets that are worn. However, an experimentally derived correction factor will then be needed to calculate the extremity dose see Vanhavere et al., 2008 [62]

Annex 9 Skin Dosimetry

There is no formal guidance on methods for calculating skin doses so this annex provides information and guidance based on practical experience and includes a non exhaustive list of different methods that can be used to measure, assess and estimate skin dose following a contamination event.

If an individual sustains skin or clothing contamination an estimate of the dose to the skin may be calculated by the employer from the activity concerned, the time exposed and the thickness of the skin at that location. Where reasonably practicable the aberrant radioactive substance sample shall be retained for dosimetry assessment. Activity/dose rate conversion factors are applicable for a single particle for estimating dose, but alternative values should be used for uniform contamination deposits. It should be borne in mind that in some circumstances doses from absorption of activity through the skin may be more significant than the skin dose itself (e.g. contamination by tritiated water). If the estimated dose to the most exposed square centimetre of skin is greater than 5 mSv a site RPA should be consulted and a formal assessment of dose carried out. In cases of a wound site, especially where there is the potential for significant internal exposure, there may be a number of uncertainties and consideration should be given to having a formal assessment by an ADS.

Superficial Whole Body Dose: Depending on the type of radiation field an individual is exposed to whilst at work, for example a 'hard beta' component such as Sr-90, there may be a requirement to assess the superficial exposure (or skin exposure) using a suitable dosemeter that measures Hp(0.07).

Planned Non Uniform Exposure: In the case of non uniform external radiation the whole body dosemeter may not be adequate to assess the dose to the skin/extremity. However, the dose can normally be assessed by an extremity dosemeter.

Contamination of Skin/Clothing: Localised direct irradiation of the skin may occur due to contamination of skin or clothing. This situation can occur due to a breakdown in procedure or accident and may result in an un-assessed component of dose. The skin dose is mainly due to weakly penetrating radiation, particularly beta radiation.

In the case of skin contamination, quick decontamination is of the utmost importance, however it is also important to ensure that adequate information is recorded at the time of the contamination incident to allow a skin dose assessment to be carried out if necessary. A skin dose assessment is likely to be required in cases where the contamination cannot be totally removed from the skin by decontamination procedures and when it is expected that the skin dose exceeds an action level or limit.

Assessment of Skin Dose Following Contamination

This section provides guidance on assessment of skin dose from a personal contamination event. This is required if the contamination is likely to have resulted in a significant non-assessed component of dose.

There is no formal guidance on methods for calculating skin doses so the following information is based on practical experience and includes a non exhaustive list of different methods that can be used to estimate skin dose following a contamination event.

Consideration should be given to consulting an external body such as the Health Protection Agency, Radiological Protection Division or an appropriate ADS for advice, if it is likely that a significant skin dose has been received.

Following a personal contamination event, any activity should be retained if possible, but removed from the skin to minimise the dose. As much detail should be recorded about the contamination detected, taking into account the factors below that need to be considered in making a skin dose assessment.

Type of instrumentation used to detect and measure the activity will depend on the contaminant. Each type of probe has a different efficiency for different isotopes so it is important that the type of probe used is recorded.

Isotopic composition of activity: Analysis techniques such as gamma and alpha spectrometry may be used to ascertain any gamma and alpha emitters present respectively and then beta emitters can be inferred from the fingerprint (ratio of isotopes in the area) if known. Direct measurements can also be used to assist in determining if hard/soft betas are present by using various shielding materials between the probe and the contamination, although soft betas are particularly hard to detect. It is important to consider the decay products of certain isotopes, depending on the half life of the parent nuclide. One example is plutonium which is normally a mixture of plutonium isotopes, one of these being Pu-241 with a half life of approximately 14 years. It decays to U-237 and Am-241, so these isotopes may also be present. This may affect the dose received due to the different emissions of the daughter radionuclides.

If it is not possible to determine the composition then pessimistic assumptions need to be made about the isotopes present based on information such as work area prior to the incident.

Concentration of radionuclide on the skin or clothing in Bq/cm^2: The activity can be estimated from instrument probe readings (taking efficiency for the particular isotope into account) or by removing the contamination and using measurement techniques such as gamma spectrometry. This relies on having a good knowledge of isotopes present in the area to ensure pure beta emitters are taken into account.

The area of contamination also needs to be estimated. This is particularly important if the area of contamination is less than the area of the probe, due to averaging.

Self shielding aspects of the material may need to be taken into account if the emissions are low energy gamma/X-rays to ensure that activity present on the skin is not underestimated: for instance low energy L X-rays from plutonium where the PuO_2 is about 6mm.

Time of exposure/Retention on skin: The time the activity was present on the skin/clothing prior to detection needs to be estimated. If the contamination is gradually removed from the skin, a record should be kept of the level of activity at particular points in time.

Shielding of clothing/Distance: If the contamination is present on clothing and not directly on the skin then the clothing may provide some shielding and increase the distance of the activity from the skin, thereby reducing the dose to the skin.

The location of the contamination needs to be confirmed, for instance if contamination is detected on a glove, it is important to determine whether the contamination is on the inside or the outside of the glove. The glove may provide some shielding for the skin from contamination on the outside, thereby reducing the dose to the skin.

If a practical measurement is being carried out to determine the skin dose then the impact of the clothing can be taken into account by the position of the extremity dosemeter relative to the activity. An extremity dosemeter could also be used to measure dose from contaminated clothing on a model/phantom.

Half life of radionuclide: If the half life of the radionuclide is comparable to the time that the activity is present on the skin then this will have an impact on the assessed dose due to physical decay.

Depth of activity penetration: The potential for the activity to have penetrated through the skin into the body should be considered and if this is possible, there is a need to consider internal dose assessment (see chapter 5). This may occur due to the chemical form of the radionuclide or if it is dissolved in certain solvents.

Contamination incorporated in a wound: If activity is detected in the wound then this would also require consideration of internal dose assessment as the activity may pass into the body. See chapter 5.

Skin Thickness: The Assessment of Skin Doses should generally be evaluated at a mean basal cell depth of 70µm. However, in the case of non-uniform exposure, it may be necessary to use the basal cell layer depth for the skin area of interest. If this is the case, then methods 1 or 4 listed below could be used for calculating the dose, as skin thickness is taken into account. An example of this would be contamination of the fingertips where the skin thickness is 40mgcm^{-2} or 400µm.

Skin Dose Practical Measurement and Assessment

Skin Dose Assessments should be carried out by practical measurement where possible. This is possible if the activity has not been immediately washed off.

If the activity is particulate, the activity should be removed from the skin onto sticky tape, then a reconstruction of the situation can be prepared possibly using a model or phantom and a TLD to simulate the surface of the skin and measure the dose.

For example, if the activity was detected on the outside of a glove then a extremity dosemeter (simulating the skin) can be placed inside the glove beneath the activity for a known period of time to measure the radiation being emitted. A dose estimate can then be calculated if the length of time the activity was present on the glove whilst it was being worn is known.

Another example is if there is some residual activity on the surface of the skin that cannot be removed, then the dose from this known level of activity may be measured by taping a extremity dosemeter to the contamination. If the extremity dosemeter is a fingerstall then this may need to be turned inside out. The dose from the initial activity present on the skin could then be estimated based on the results. (Every effort should be made to remove the contamination from the skin to minimise the exposure but if it is

not easily removed, advice should be sought from occupational health as breaking the skin needs to be avoided due to potentially allowing contamination into the body.)

If the activity has been washed off and not retained on tape, then a theoretical calculation will be required as detailed below. The method used to estimate the dose will be dependent on the situation. The more methods that are used to estimate the dose, the more confidence there will be in the result, assuming there is good agreement.

It may be necessary to provide reassurance counselling to any individuals requiring a skin dose assessment following a personal contamination event. Refer to Chapters 3, 5 and 6 for further information.

Skin Dose: Methods of Theoretical Assessment

There are a number of methods available for estimating skin dose, some of which are discussed at Annex 10. No recommendations are made in this guide as to which of the methods of calculation should be used but it is worth noting the limitations and assumptions of each method.

It is considered good practice to carry out a practical measurement using a extremity dosemeter, but circumstances will dictate whether this is possible. If a practical measurement cannot be carried out, it is worth using a number of different calculation methods to estimate the skin dose, to see if the result is realistic and provide some confidence in the value obtained, assuming there is good agreement between the results.

Annex 10 Methods for Theoretical Assessment of Skin Dose

There are a number of methods available for estimating skin dose, some of which are discussed below:

Method 1: Based on 'Calculation of the Dose to the Basal Layer of Skin from Beta/Gamma Contamination', A. R. Curran, Journal of Society of Radiological Protection 6(1) 1986 [43].

This method for estimating dose is based on surface contamination and penetrated contamination and takes skin thickness into account. In the paper it only gives the necessary information for certain isotopes so a method of dose calculation would need to be adapted for other isotopes.

Method 2: Based on IAEA-TECDOC-1162 Skin Contamination: To assess skin beta dose from material deposited onto skin or clothing [44].

This is a simple method for assessing skin dose assuming contamination is uniformly spread over the skin. It is assumed that penetration of contamination can be neglected, that the dose equivalent values are calculated for a depth of 70μm and that the dose is due to beta radiation as the gamma contribution is only a few percent.

Method 3: Radionuclide and Radiation Protection Data Handbook 2002, D Delacroix, JP Guerre, P Leblanc, C Hickman [45].

This method is based on doserate conversion factors for a uniform deposit and a small droplet. The same assumptions are made as for method 2.

Note: This publication does make use of earlier versions of Varskin (mod 2 for beta radiation and mod2 modified for monoenergetic electrons) to calculate skin doses - see note below on Varskin 3.

Method 4:VARSKIN 3: A Computer Code for Assessing Skin Dose from Skin Dose Contamination (discussed in reference [42]).

This uses six predetermined source configurations eg. point, cylinder. The source strength, isotopic composition of the contamination and area are entered by the user. It also takes into account skin thickness and any shielding factors from protective clothing.

Note: Varskin 3 Version 3.1.0 corrects a programming error in earlier versions of Varskin 3 that occurred when calculating the percent of electronic equilibrium established for the photon dose model. In general, the correction will result in lower doses calculated for radionuclides that emit high-energy photons, especially at shallow skin depths. Although this correction makes photon dose calculations more accurate, it still assumes that the photon source is a point source: and build up as a function of depth is not modelled (see www-rsicc.ornl.gov/rsiccnew/varskin-bug.htm for details).

Method 5: The 'Guide of Good Practices for Occupational Radiological Protection in Plutonium Facilities DOE-STD-1128-98' [46]

This document provides information regarding calculation of skin doses for slightly aged plutonium (~2 years) when handled through neoprene gloves (100mg/cm^2) and for significantly aged plutonium when handled using lead loaded gloves.

Method 6: ISO/FDIS 15382 Nuclear Energy – Radioprotection – Procedure for radiation protection monitoring in nuclear installations for external exposure to weakly penetrating radiation, especially to beta radiation [47]

This method involves a similar calculation to method 3. It assumes that the activity has not penetrated the skin. The document discusses the transmission factors of protective clothing such that this can be taken into account if appropriate.

Practical Example

This example shows a comparison of the calculated doses from a number of the methods discussed above with a practical measurement using a TLD.

A speck of activity was detected on the outside of a coverall in the middle of the back. The speck was removed onto a wipe and analysed by gamma spectrometry and indicated 58kBq of Co-60. The likely length of time that the coverall was worn for was a period of 4 hours and the area of contamination was approximately 1cm^2.

Practical Method:

This speck was placed against a TLD with a coverall in between the activity and TLD for a period of 4 hours.

The dose recorded by the TLD as **39.78mSv.**

Using Method 2:

Based on IAEA-TECDOC-1162 assuming speck was 58kBq of Co-60 spread over 1cm^2 for a period of 4 hours:

$H_{s,i} = C_{s,i}. CF_{8,i} . SF_{\beta} . T_e$

$H_{s,i}$ = Equivalent dose to the skin from radionuclide i [mSv]
$C_{s,i}$ = average surface concentration of radionuclide i on skin or clothing [Bq/cm^2]
$CF_{8,i}$ = skin beta doserate conversion factor for radionuclide i from Table in TECDOC-1162
SF_{β} = shielding factor to take account of shielding afforded by clothing
T_e = time of exposure [h]

Equivalent dose to skin = 58 x 10^3Bqcm^{-2} x 0.78 x 10^{-3}mSvh^{-1}Bq^{-1}cm^2 x 0.2 x 4h
= **36mSv**

Using Method 3:

Based on Radionuclide and Radiation Protection Data Handbook 2002 –Delacroix

Contamination skin dose assuming 58kBq of Co-60 spread over 1cm^2 for 4 hours:

$1kBqcm^{-2} = 7.84 \times 10^{-1}\ mSvh^{-1}$

$\Rightarrow 58kBq = 45.5mSvh^{-1}$

$\Rightarrow$ = **182mSv**

The dose calculated using this method is considerably larger than that calculated by method 2 or measured by the TLD. This is because no account has been taken of the shielding afforded by the protective clothing and assumes the contamination is directly on the skin. If this is multiplied by the shielding factor for protective clothing (coverall) used in method 2, the result would be **36.4mSv**.

Using Method 4:

Varskin 3 Version 3.1.0:

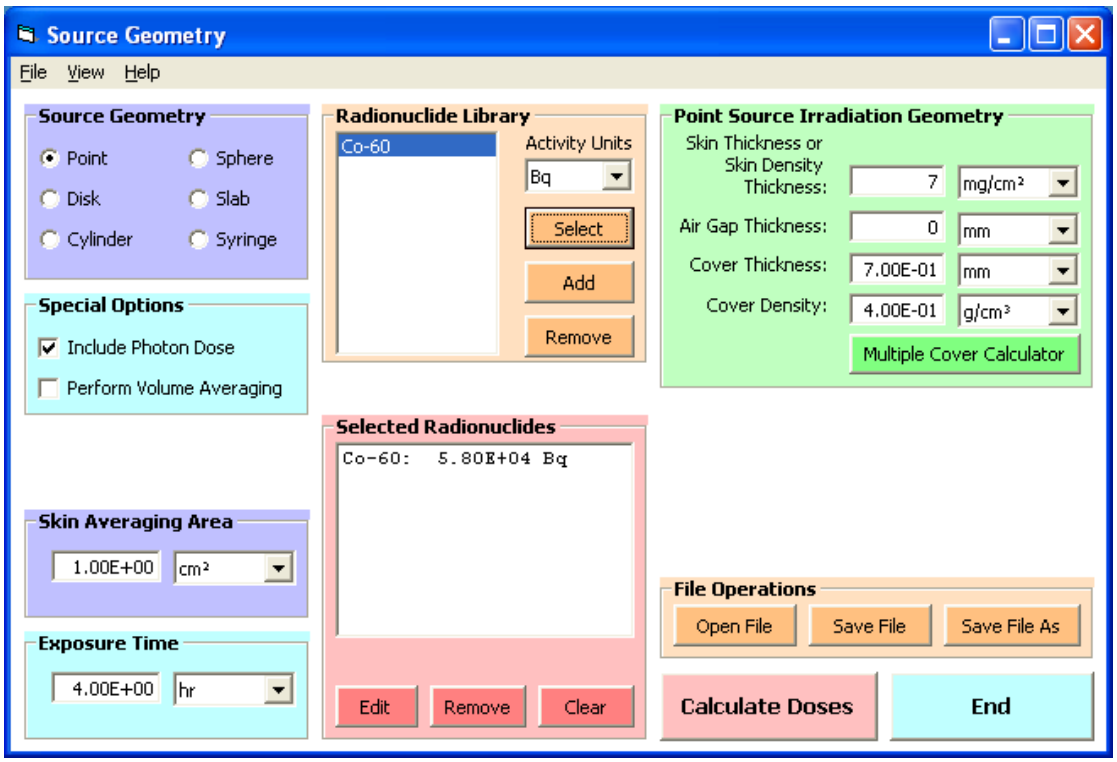

Figure 8: Varskin - Source Geometry

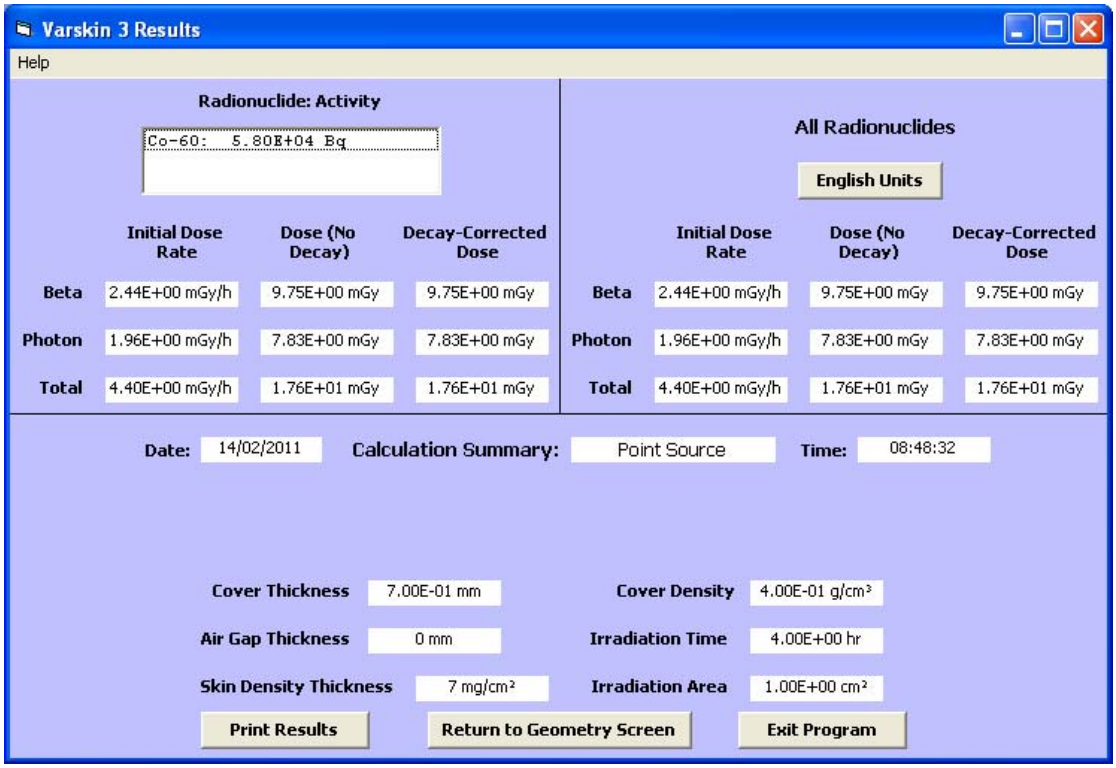

Figure 9: Varskin - Results

The dose calculated using Varskin 3 Version 3.1.0 is **17.6mSv**.

Recommendations

No recommendations are being made in this guide as to which method of calculation should be used to calculate skin dose but it is worth noting the limitations and assumptions of each method.

Good practice would be to carry out a practical measurement using a TLD, but circumstances will dictate whether this is possible. If a practical measurement cannot be carried out, it is worth using a number of different calculation methods to estimate the skin dose, to see if the result is realistic and provide some confidence in the value obtained, assuming there is good agreement between the results.

Attachment: Example International Radiation Passbooks

Insert Link to Attachment